Structure and composition of Venus atmosphere from the SPICAV/SOIR

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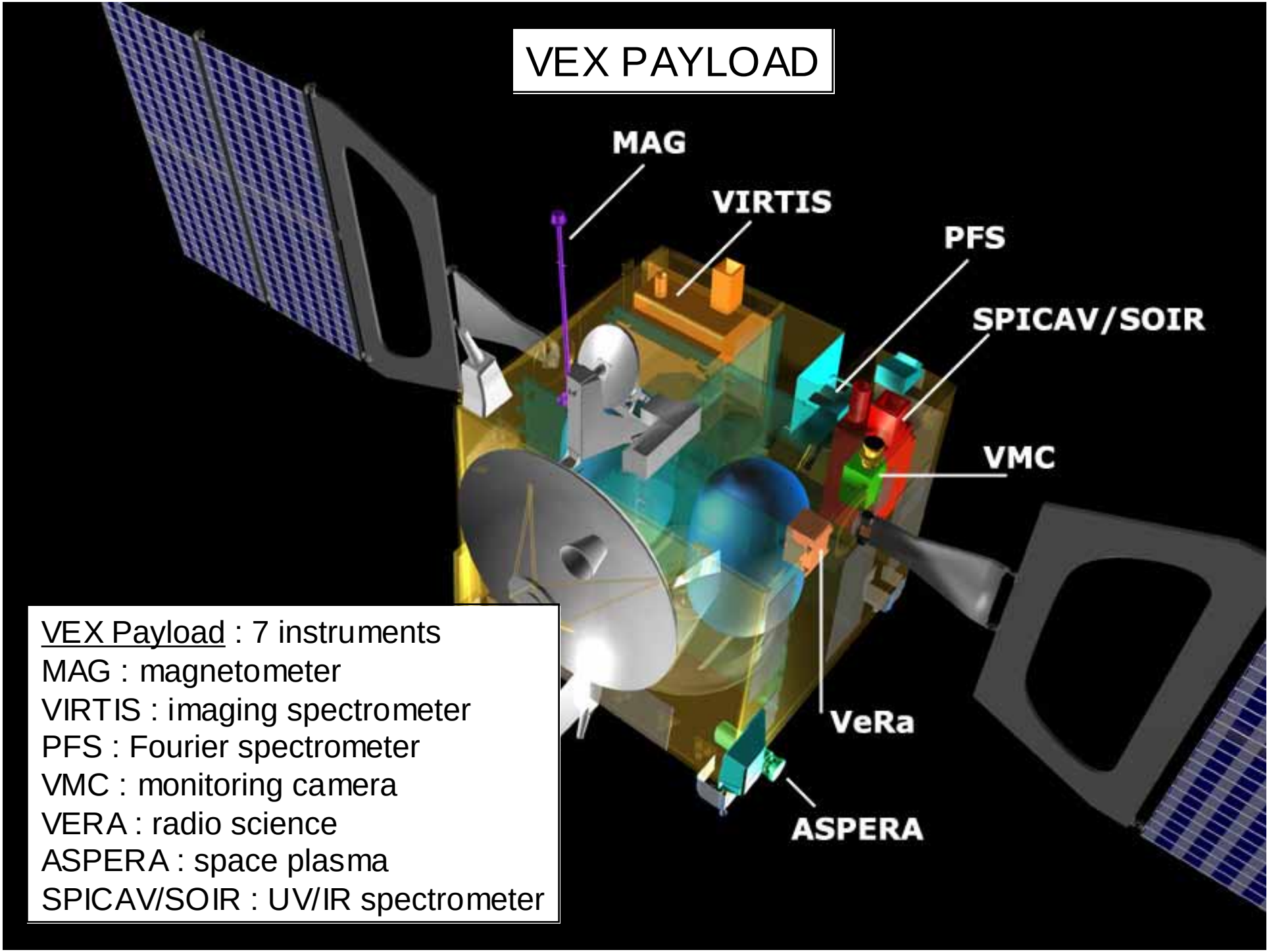
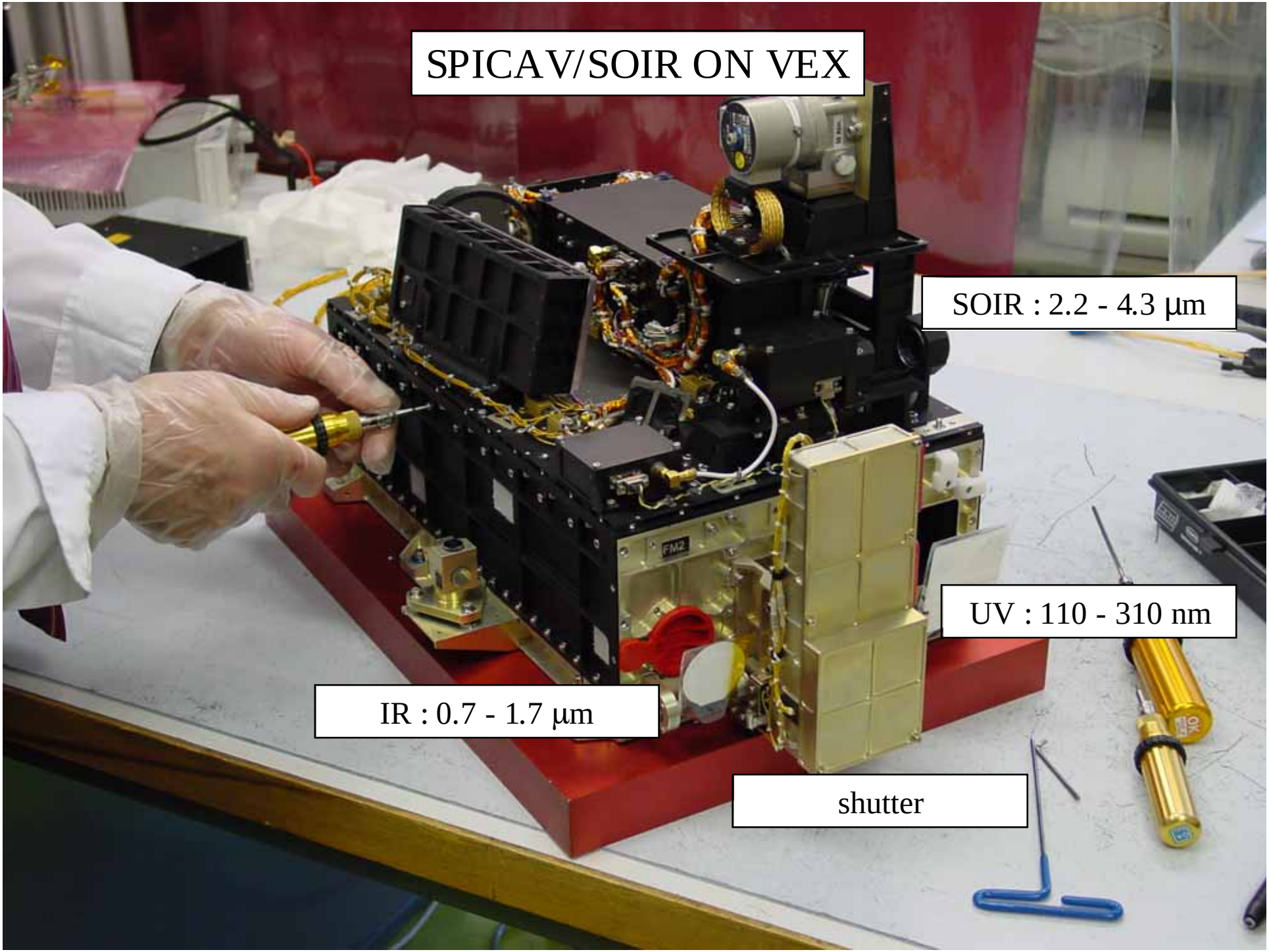
50th anniversary Sputnik celebration, IKI, Moscow, 1-4 October 2007

THE SPICAV-SOIR INSTRUMENT

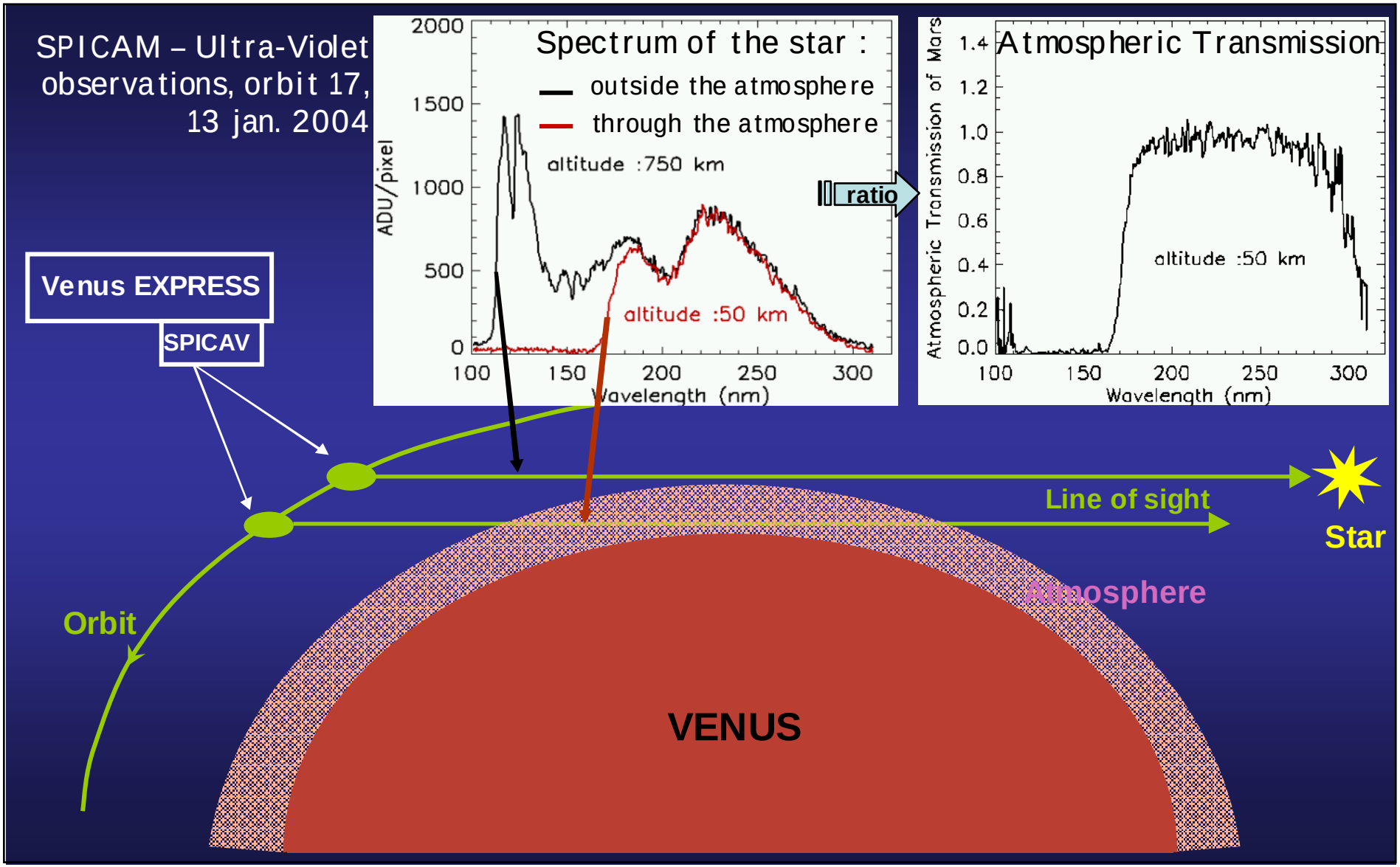
VEX PAYLOAD



VEX Payload : 7 instruments
MAG : magnetometer
VIRTIS : imaging spectrometer
PFS : Fourier spectrometer
VMC : monitoring camera
VERA : radio science
ASPERA : space plasma
SPICAV/SOIR : UV/IR spectrometer

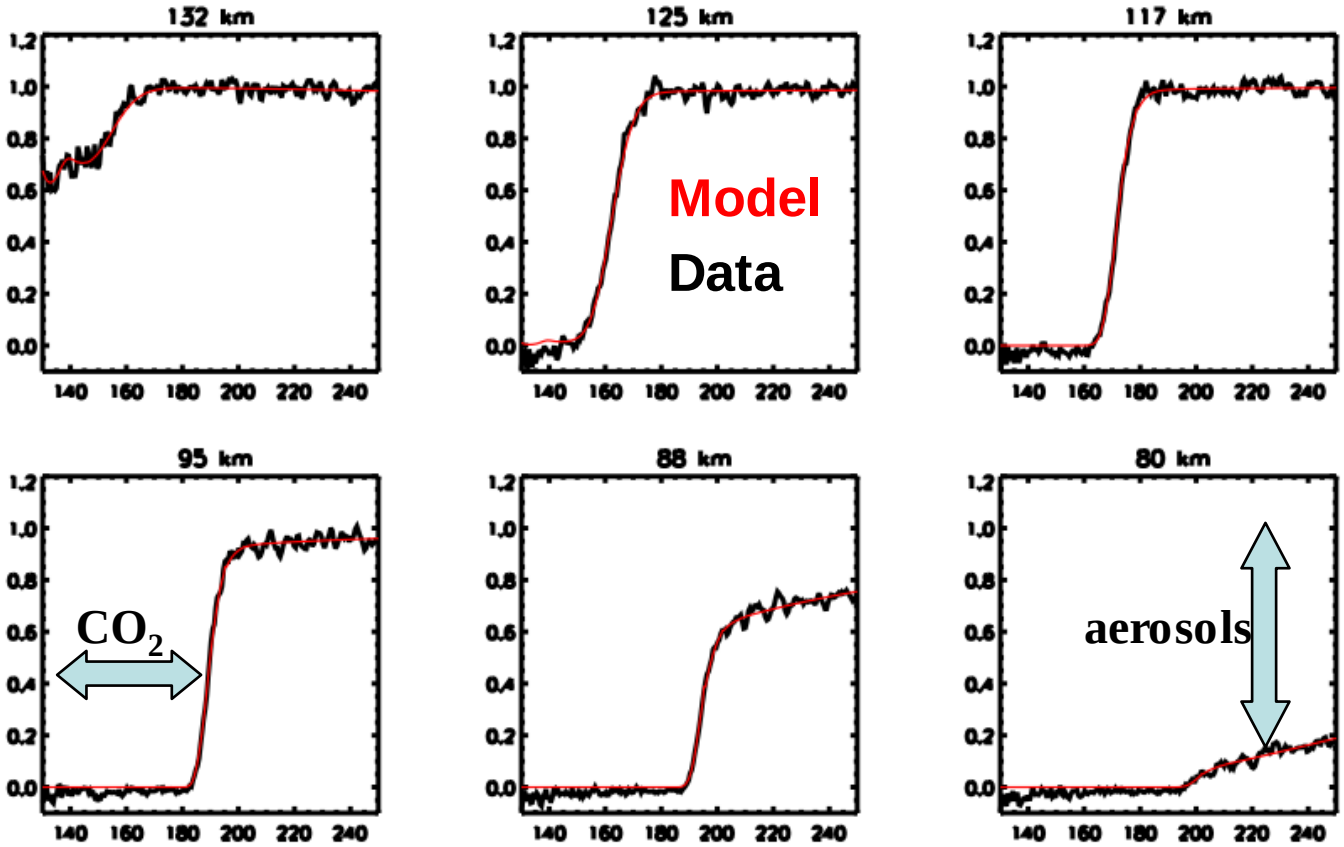

SPICAV/SOIR ON VEX
SOIR : 2.2 - 4.3 µm
UV : 110 - 310 nm
IR : 0.7 - 1.7 µm
shutter

Star Occultation:operating on Earth, Mars, Venus

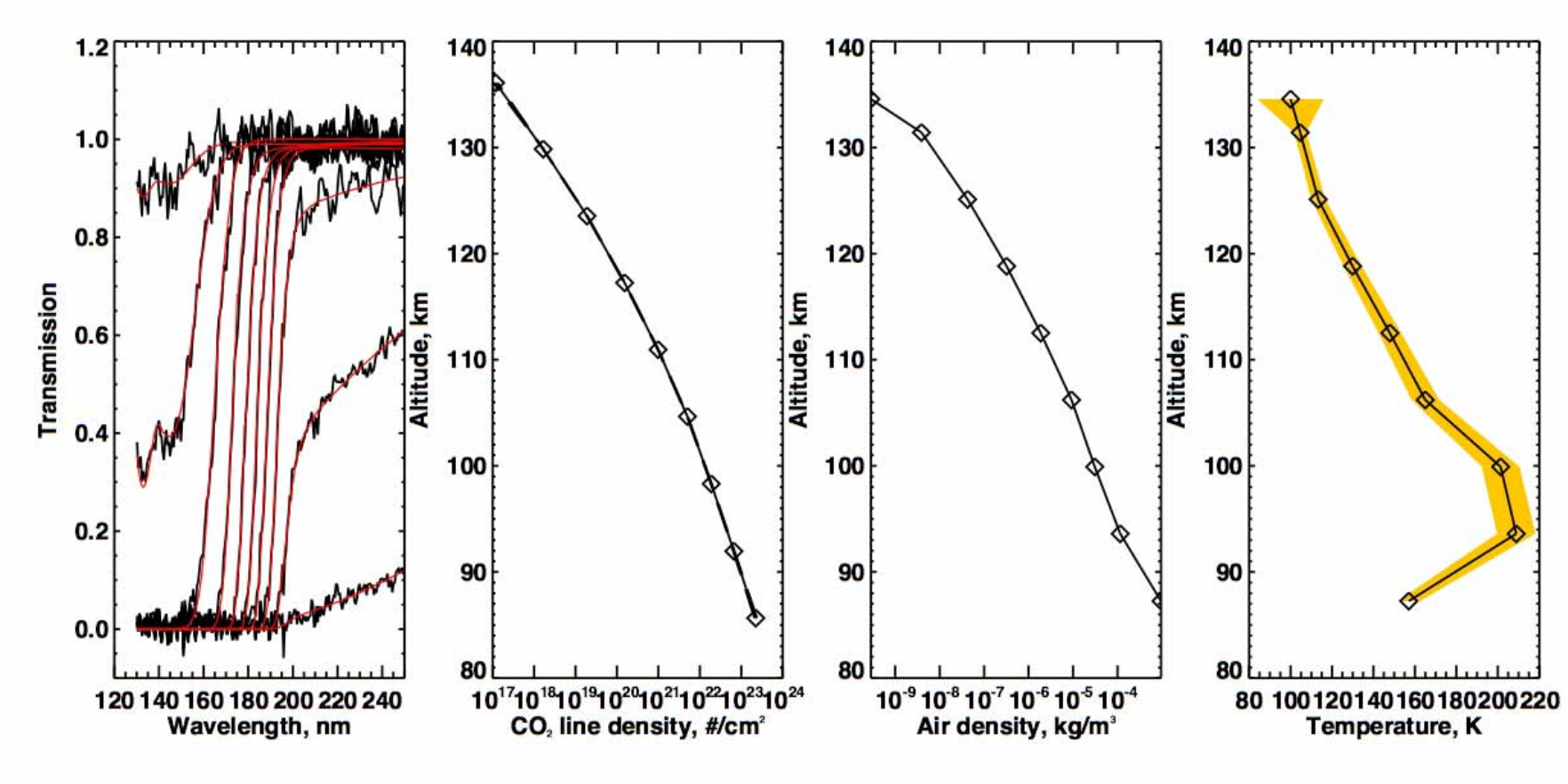


UV stellar occultation

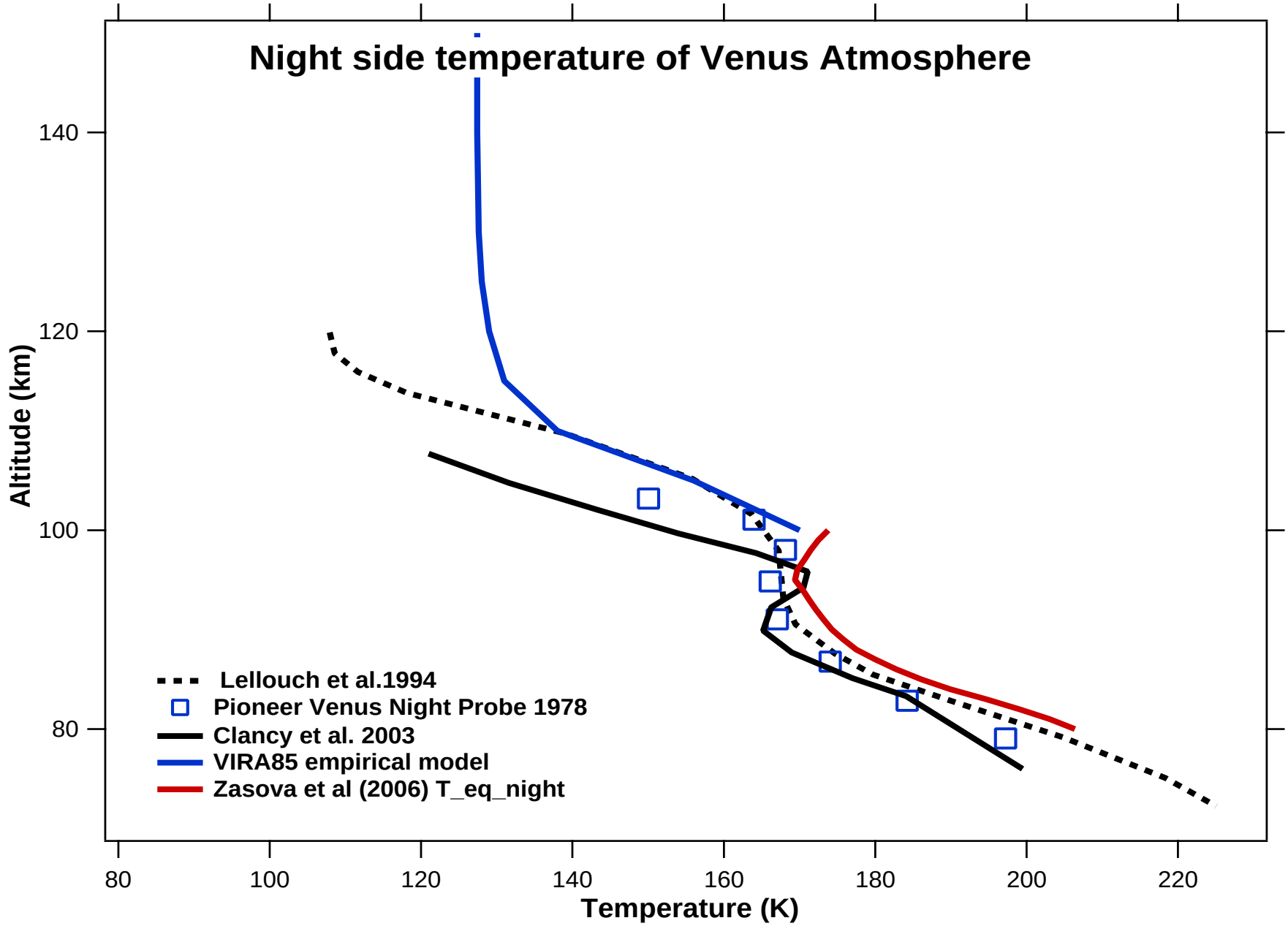
Stellar Occultation:
CO_2 and aerosol quantities inversion

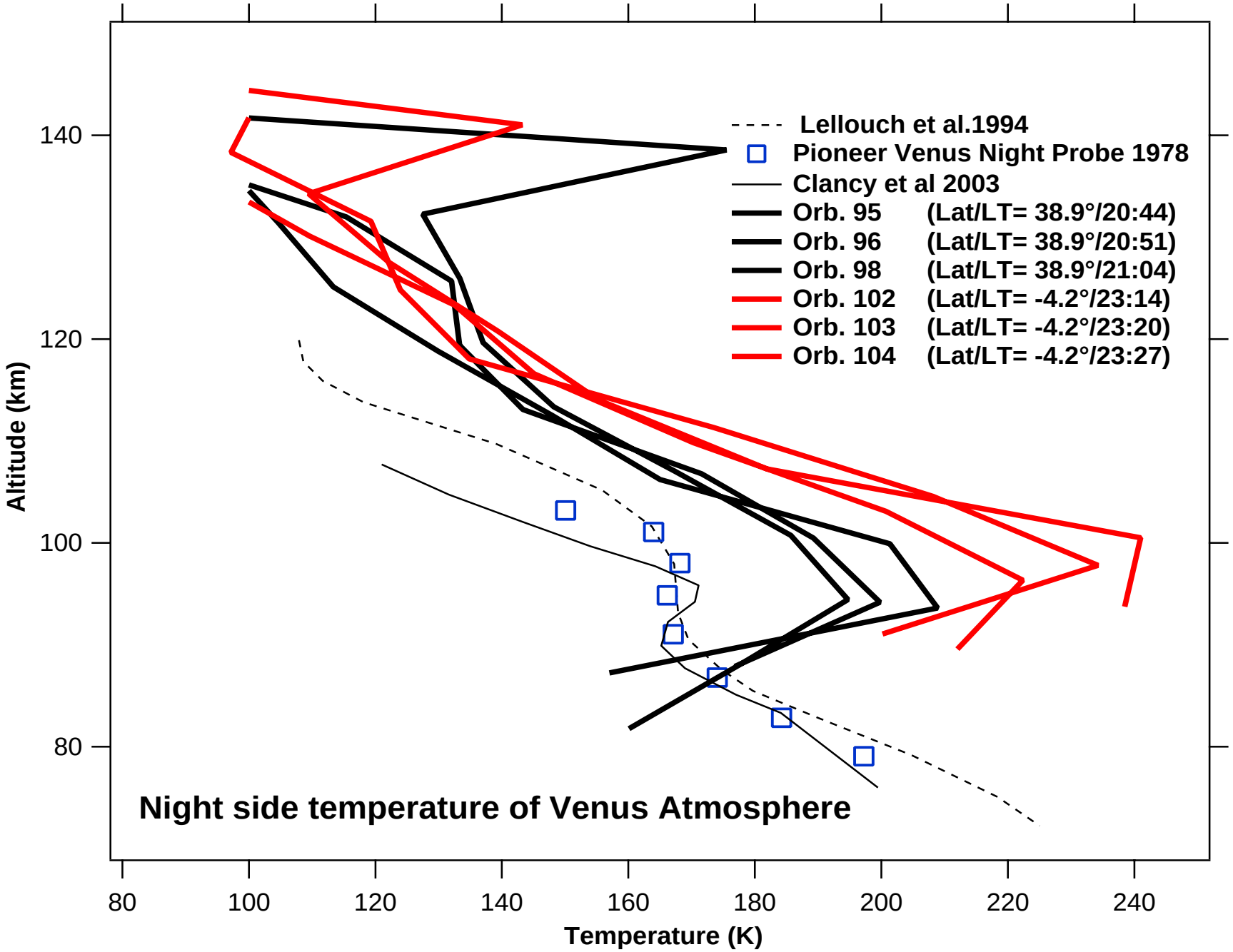


Temperature profile retrieval

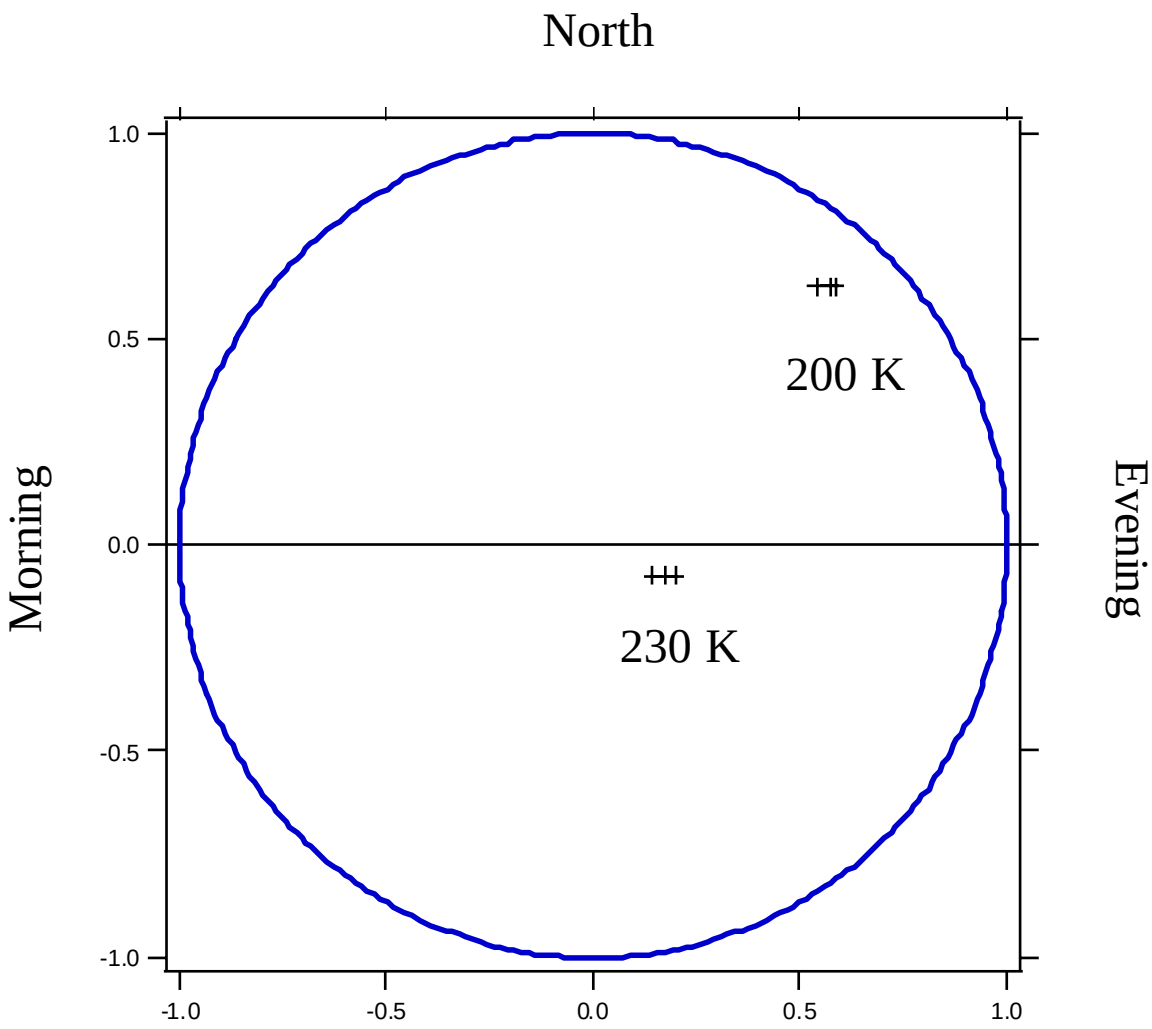


Before SPICAV/VEX: Venus Night Side mesosphere (60<Z<100 km)

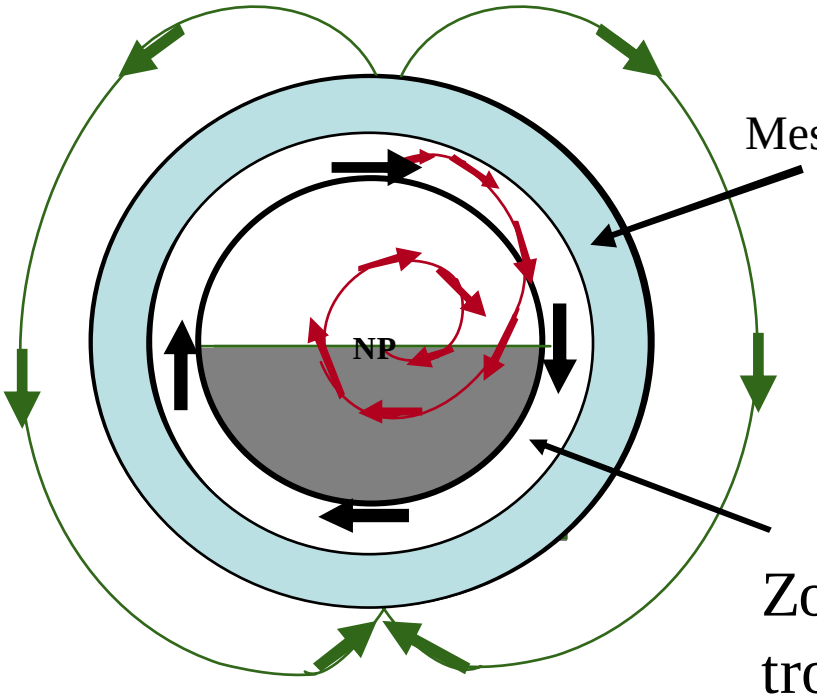



Lellouch et al.1994
Pioneer Venus Night Probe 1978
Clancy et al 2003
Orb. 95 (Lat/LT= 38.9°/20:44)
Orb. 96 (Lat/LT= 38.9°/20:51)
Orb. 98 (Lat/LT= 38.9°/21:04)
Orb. 102 (Lat/LT= -4.2°/23:14)
Orb. 103 (Lat/LT= -4.2°/23:20)
Orb. 104 (Lat/LT= -4.2°/23:27)
Night side temperature of Venus Atmosphere
Altitude (km)
140
120
100
80
80
100
120
140
160
180
200
220
240
Temperature (K)

Venus seen from night side



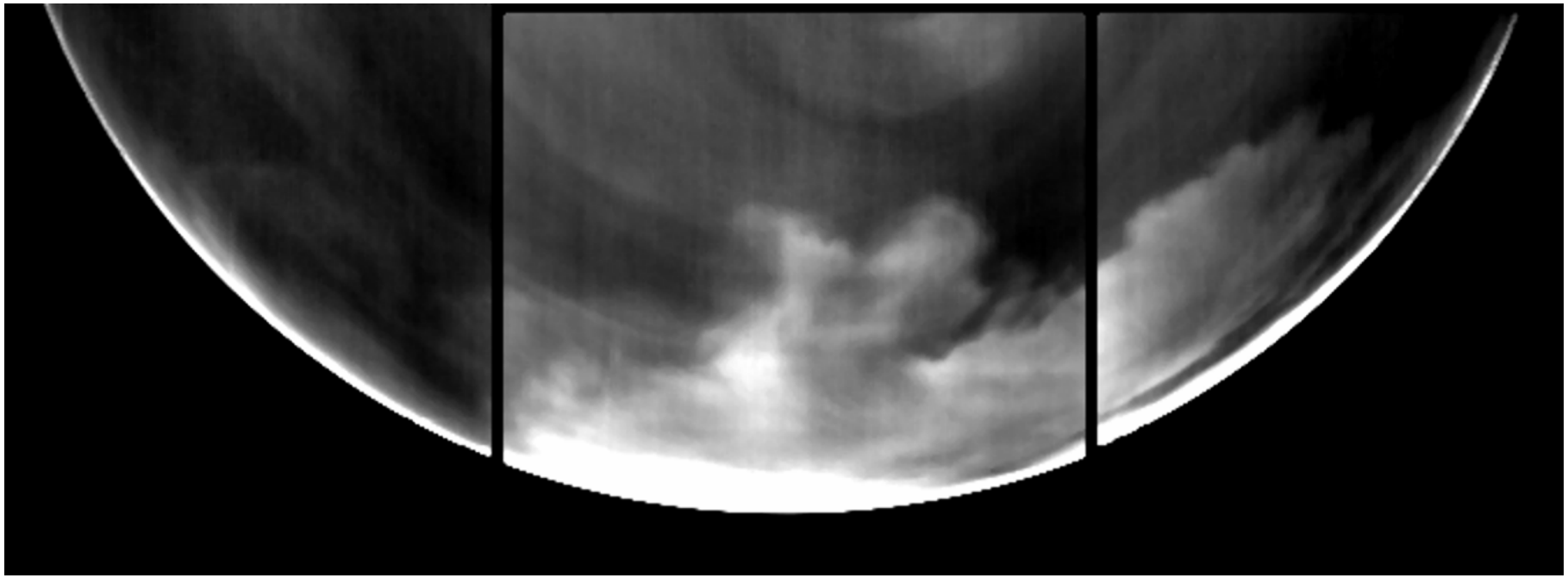
Sub-solar Antisolar circulation: thermosphere z>100 km



Region of air subsidence:

adiabatic heating, O_2, NO emissions

A VIRTIS image of O_2 1.27 µm emission, a tracer of descending air on the night side

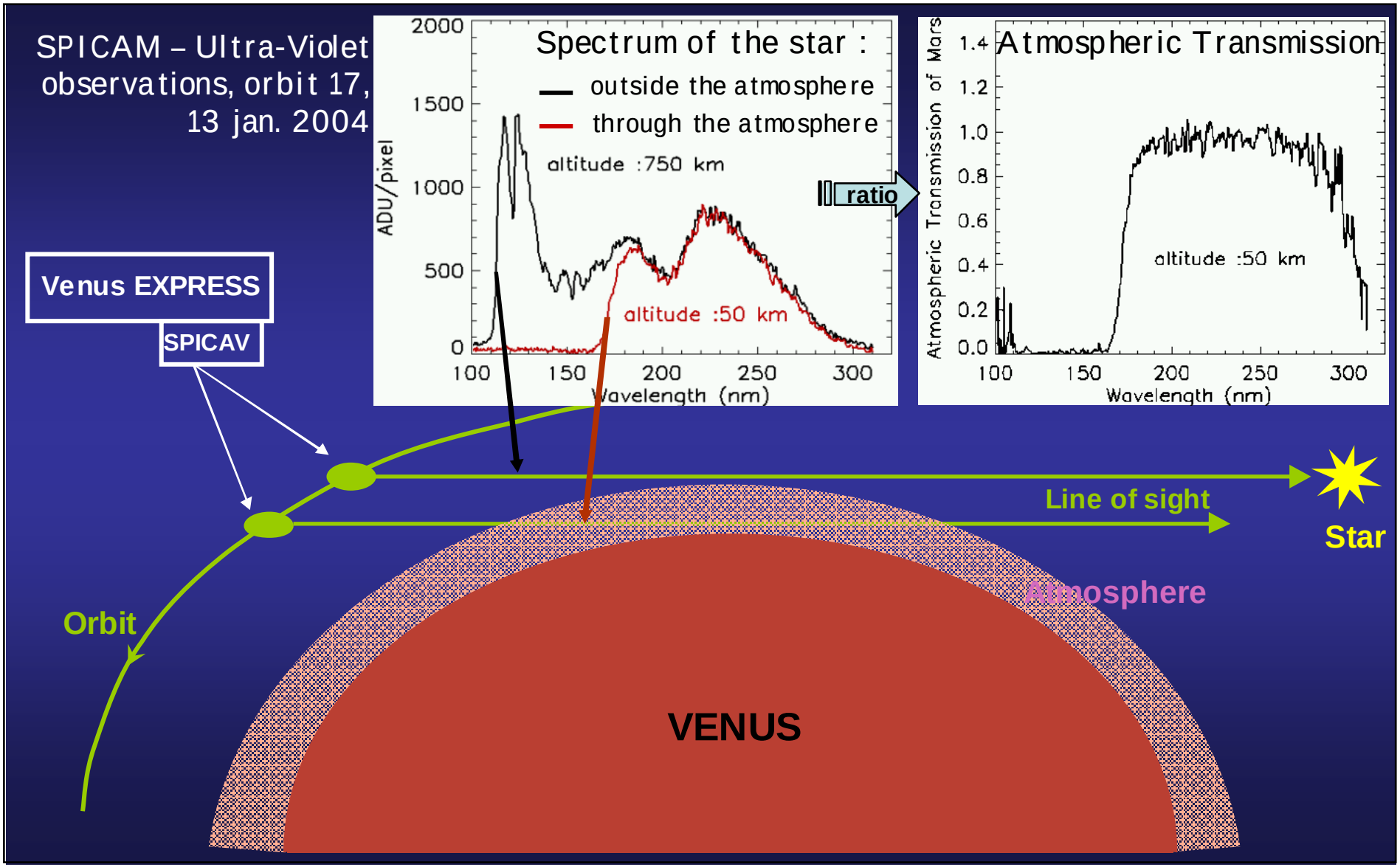


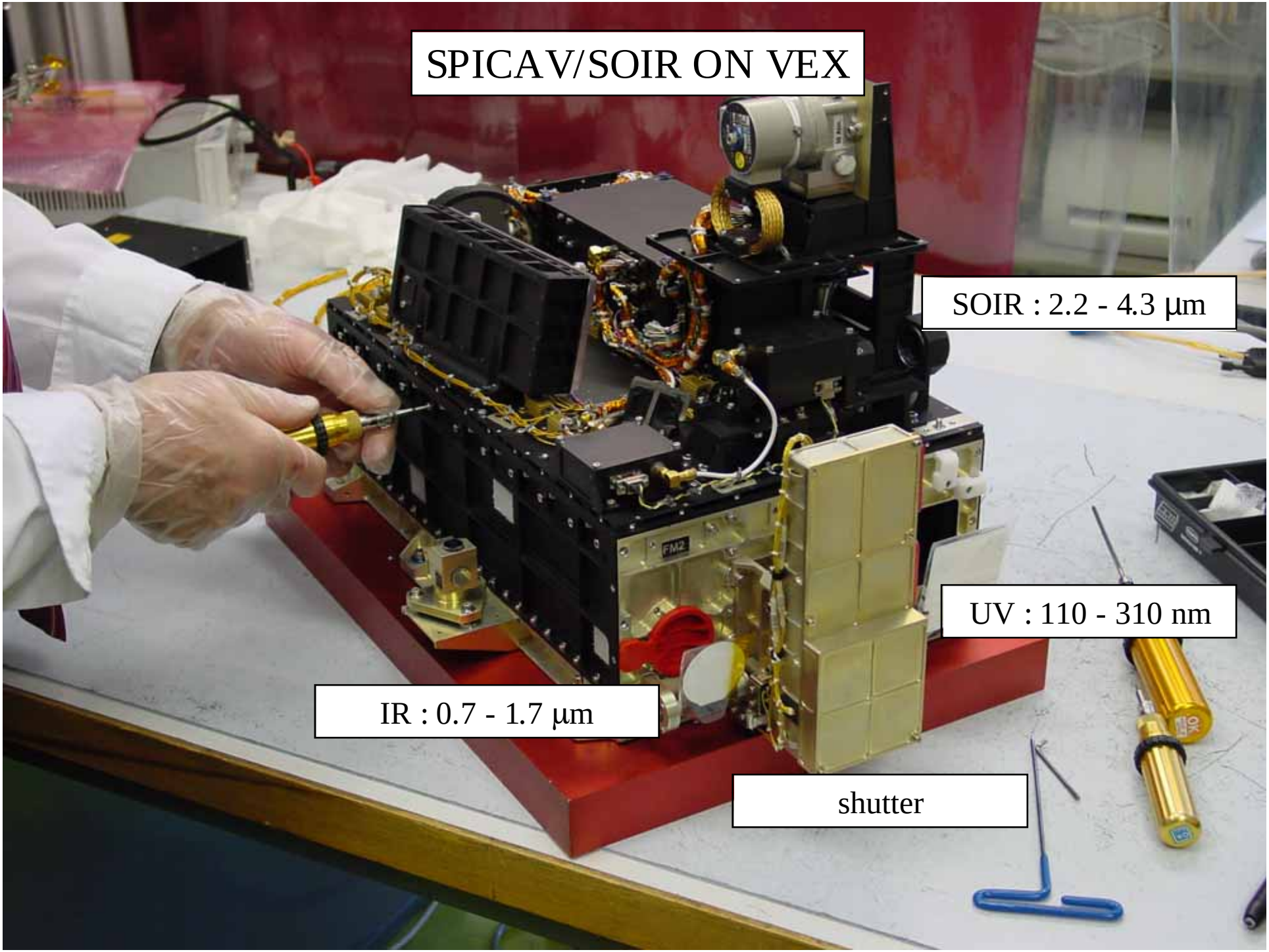
- Air descent area is large, but not on the whole nightside planet.
- Is the SPICAV hot layer distributed in the same fashion ?
- When there is O_2 emission, there is a descent

But there may be a descent without O_2 emission (if no more O atoms)

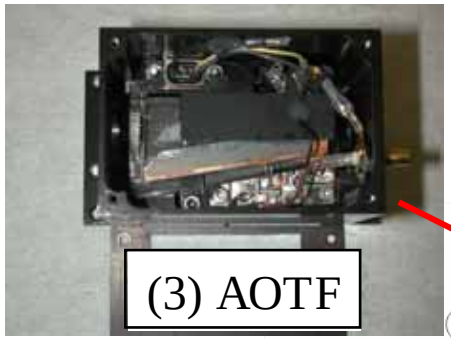
SOIR data analysis

Star Occultation:operating on Earth, Mars, Venus



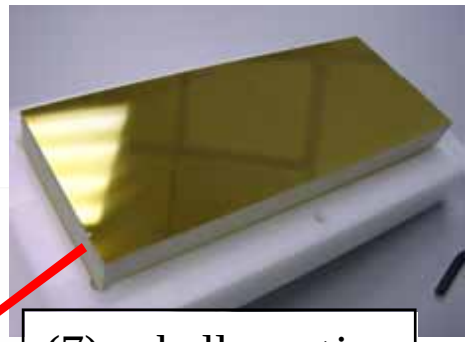

SPICAV/SOIR ON VEX
SOIR : 2.2 - 4.3 µm
UV : 110 - 310 nm
IR : 0.7 - 1.7 µm
shutter

SOIR : SPECTROMETER SCHEME (OIP,Belgium)

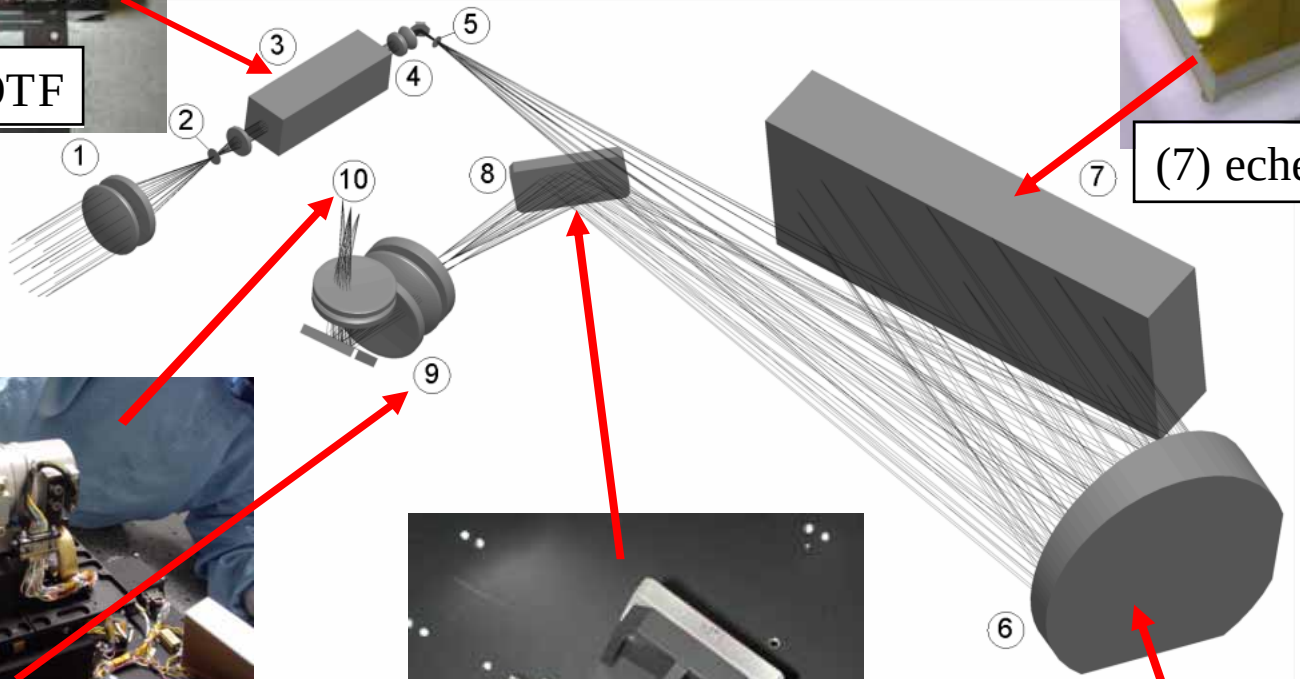


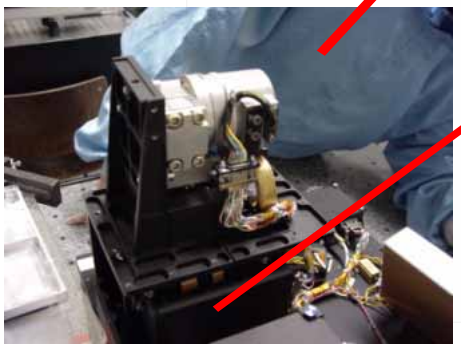
(3) AOTF

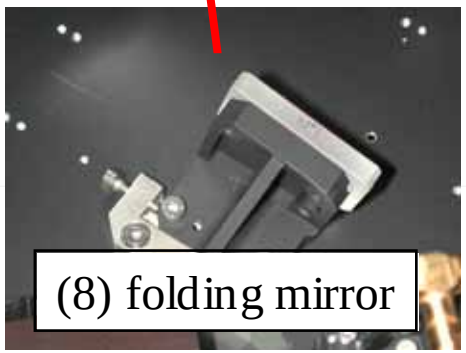
compacting exercise



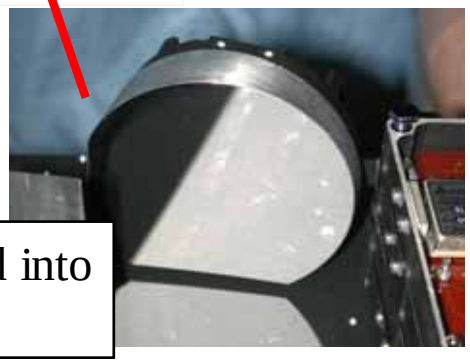
(7) echelle grating







(8) folding mirror



(9) folded detector optics
(10) detector assembly placed upright
(SOFRADIR,France)

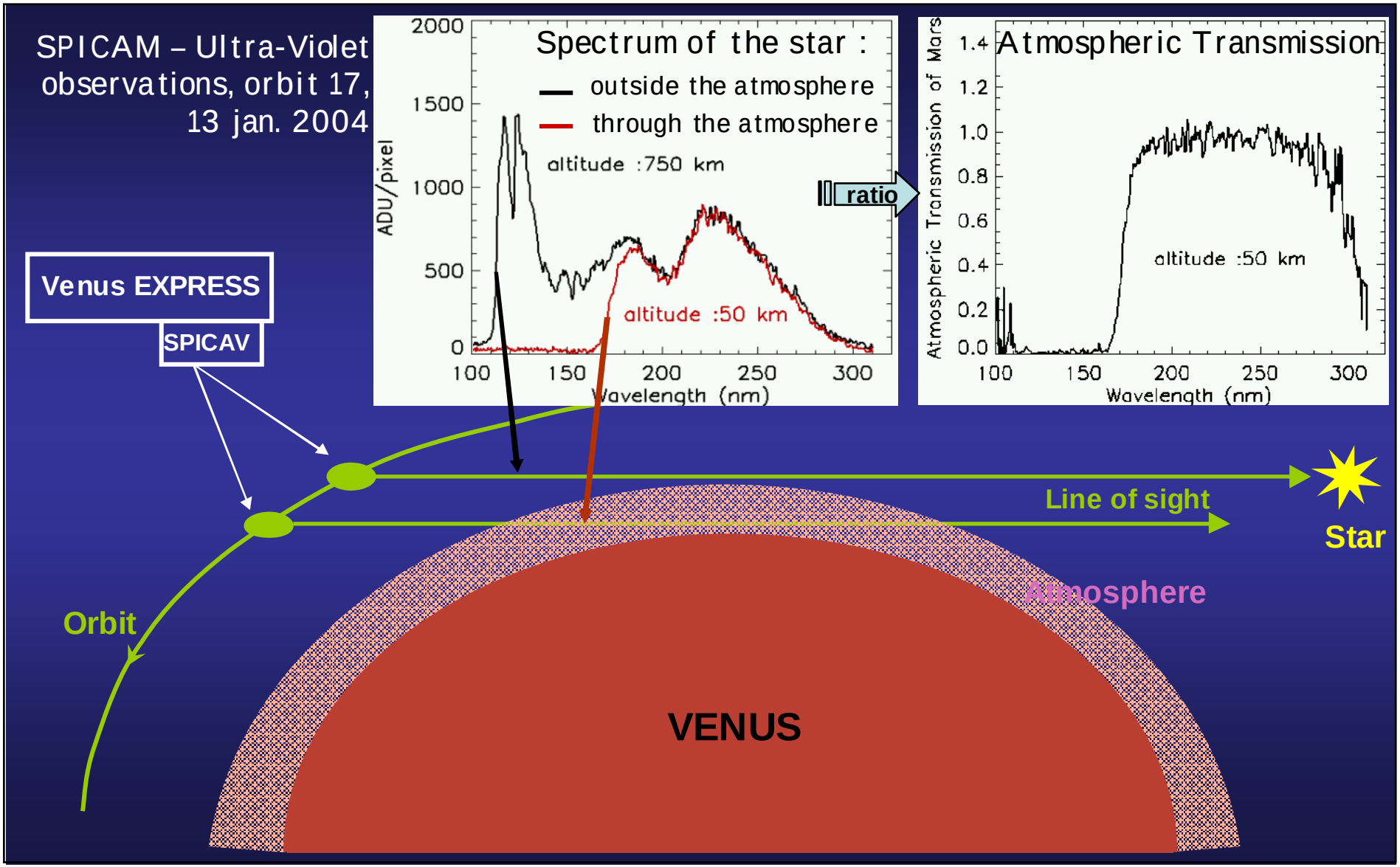
(6) collimating and camera lens merged into one off-axis parabolic mirror

HDO/H2O situation in Venus

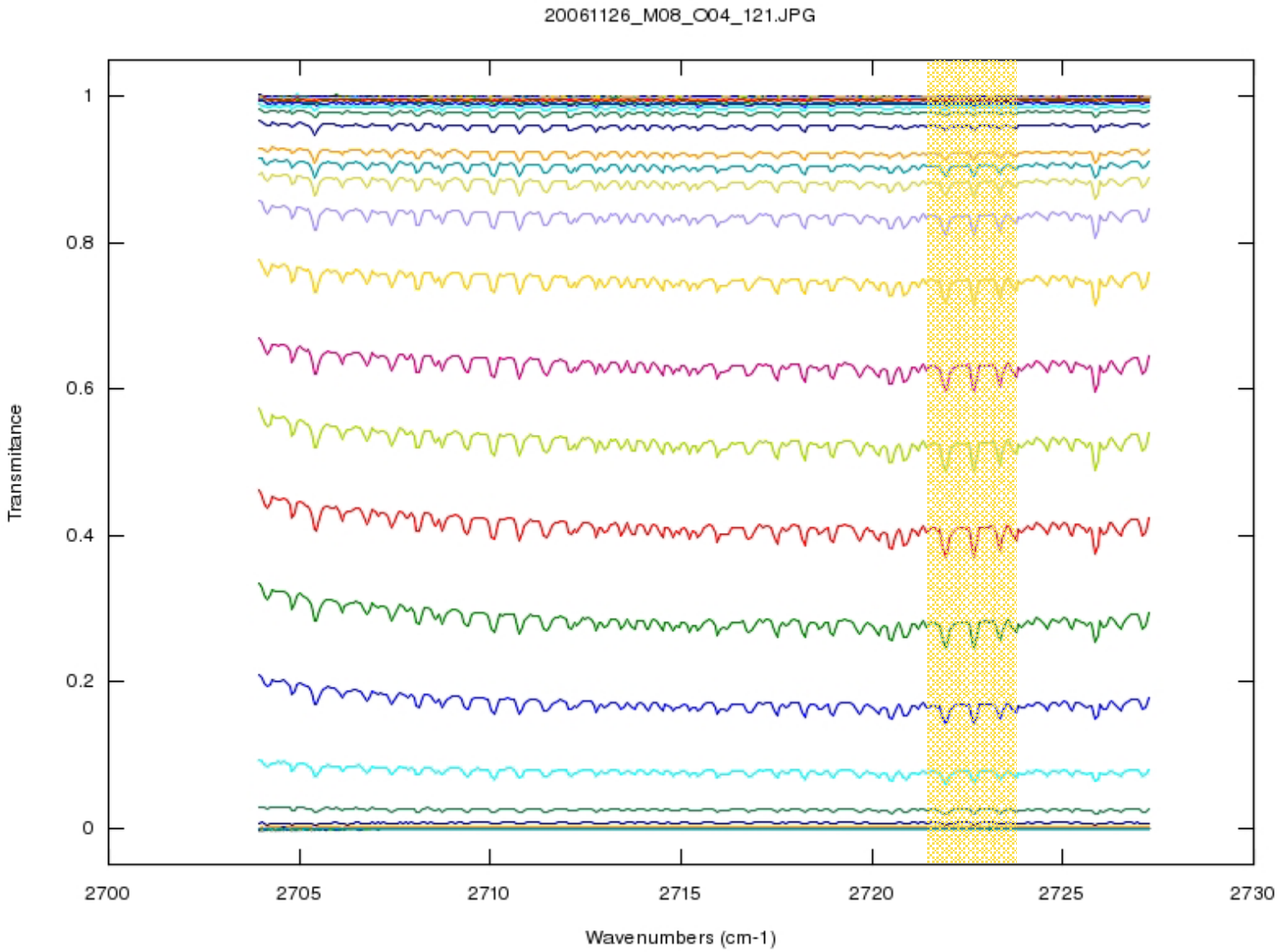
- **Present: Equivalent of 3 cm of water (liquid) in the atmosphere of Venus : Earth: 2.7 km**
- **The low atmosphere is rich in HDO: 150 times Earth value.**
- **Due to escape of H atoms, and less escape of D atoms (heavier)**
- **If there is NO escape of D atoms, then there could have been on Venus:**
- **150x3 cm= 4.5 m**
- **Preferential condensation of HDO in ice (exists on Earth at tropopause, loss of a factor of 3), could prevent D atoms from reaching escape altitude (250 km)**
- **Exists also on Mars**

- **Does it exist also on Venus ? SOIR objective**

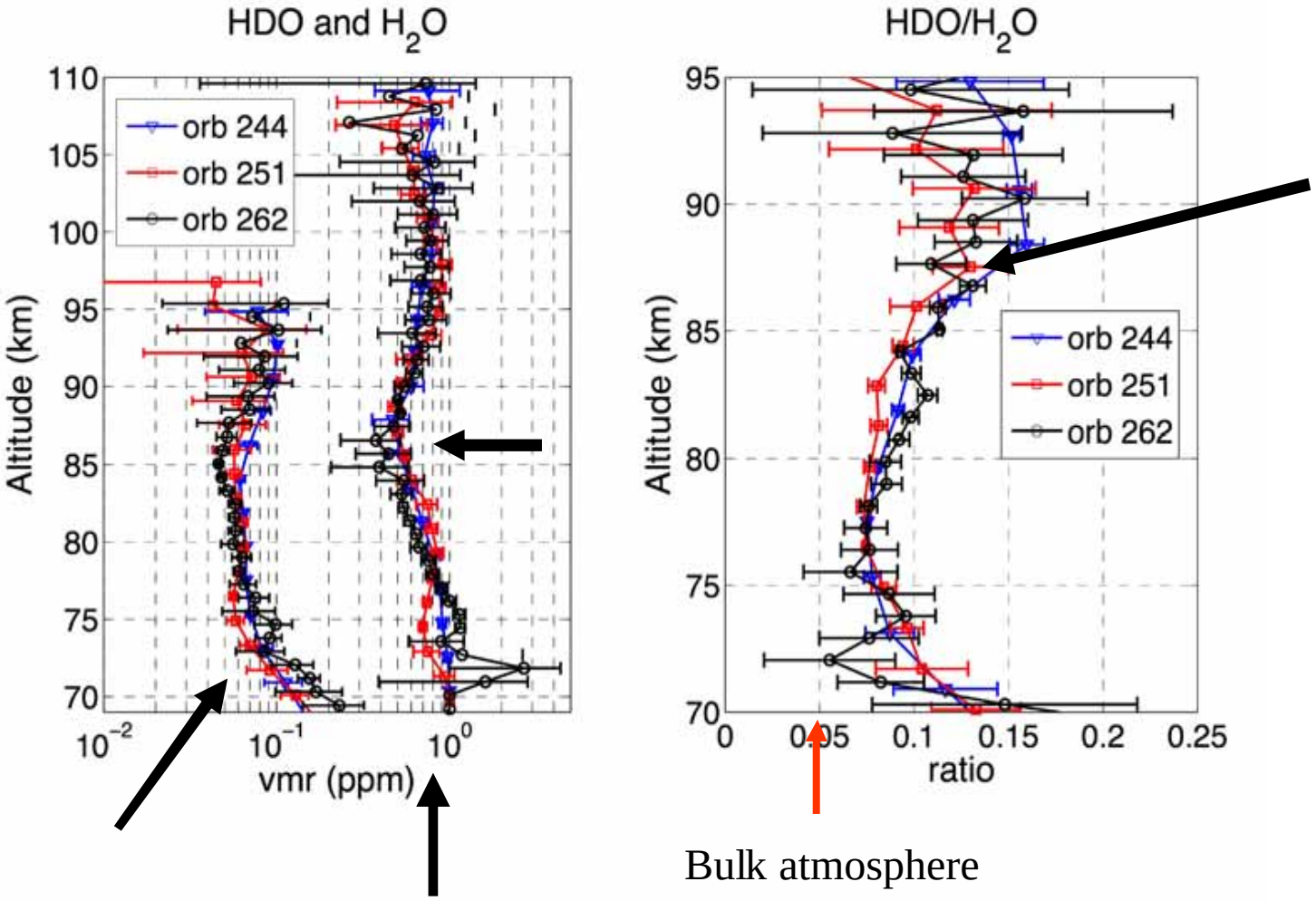
Star Occultation:operating on Earth, Mars, Venus



HDO detection by SOIR solar occultation



H_2O and HDO at 3 orbits, 75° N at terminator (solar occultation)



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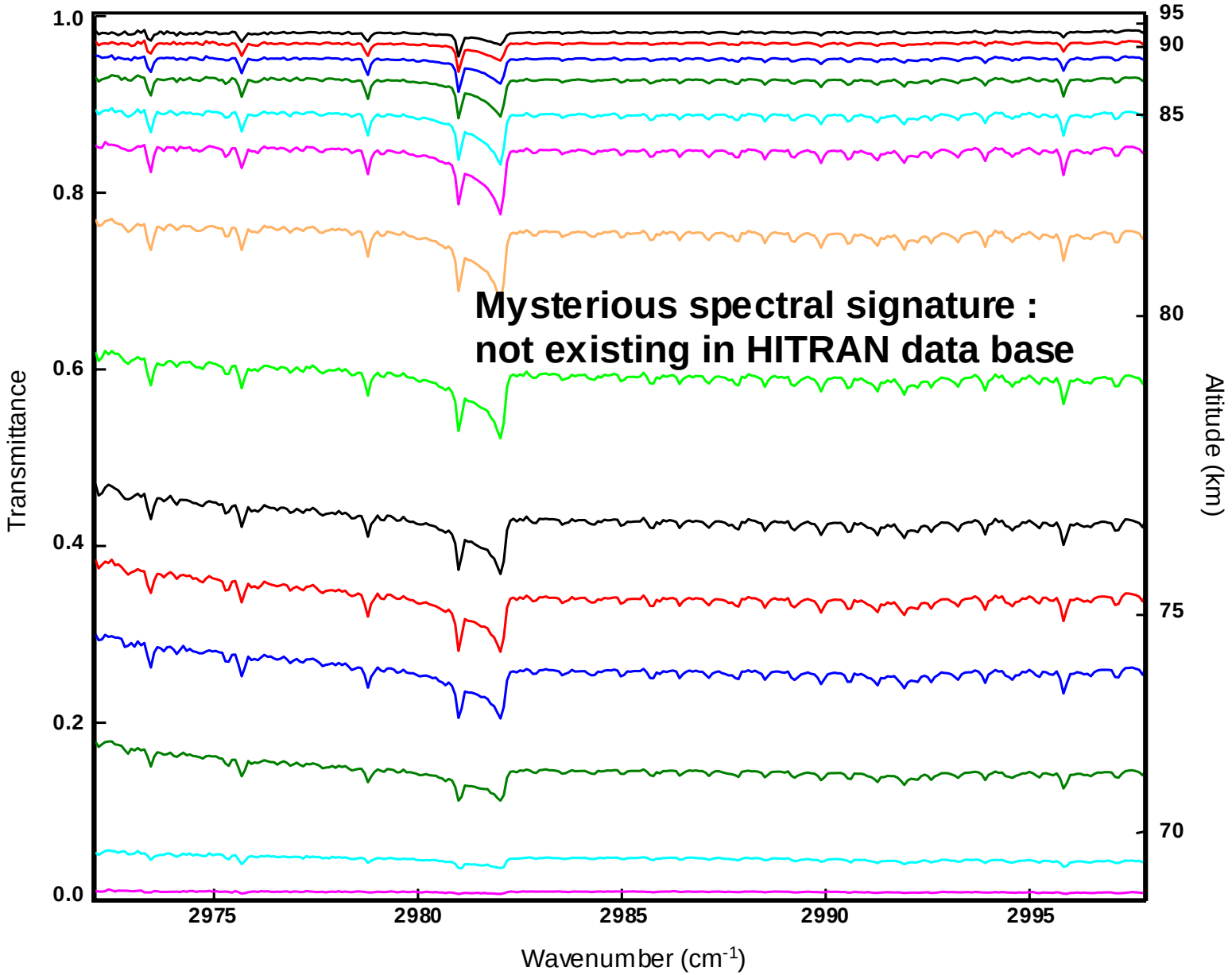
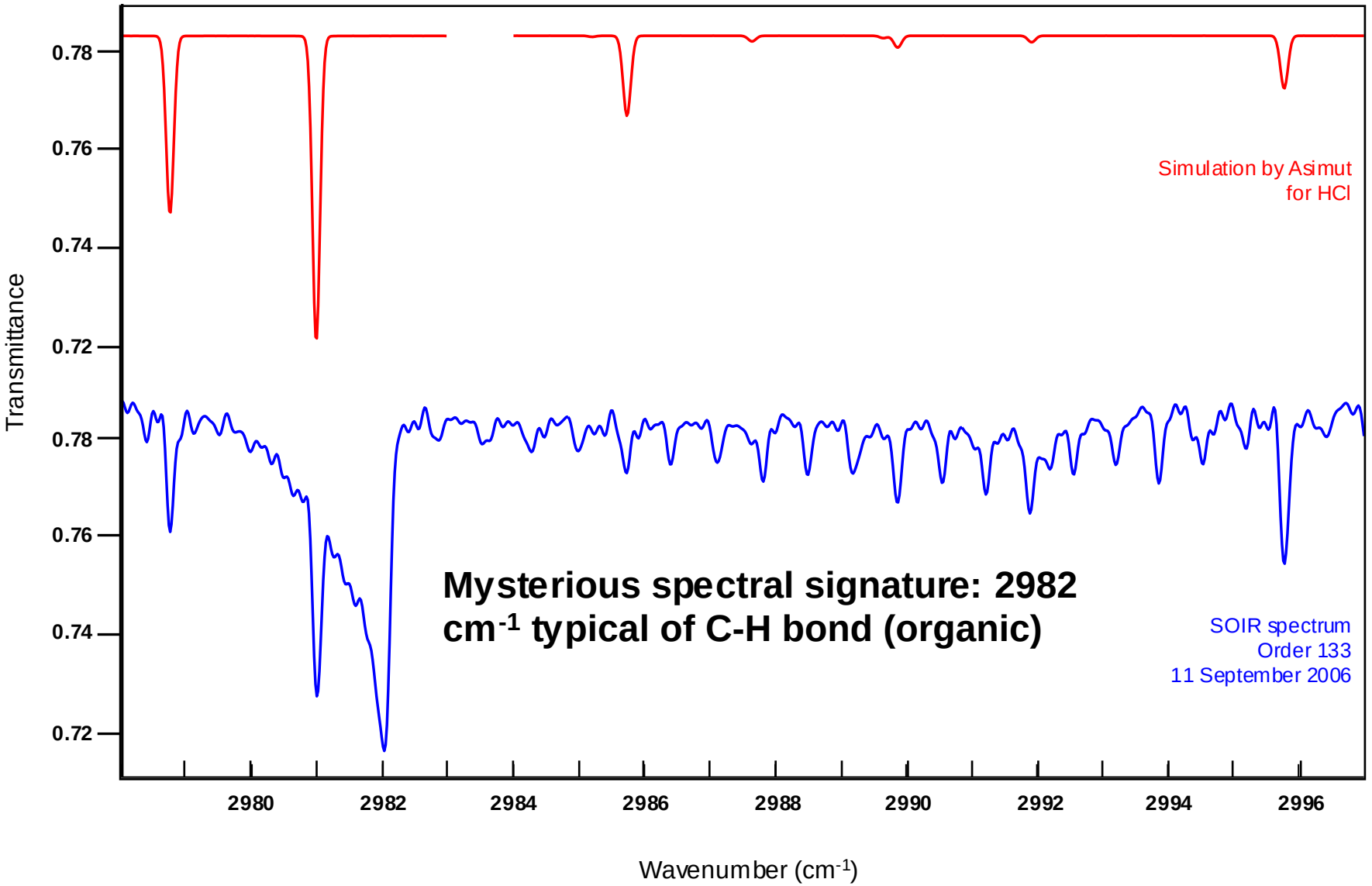
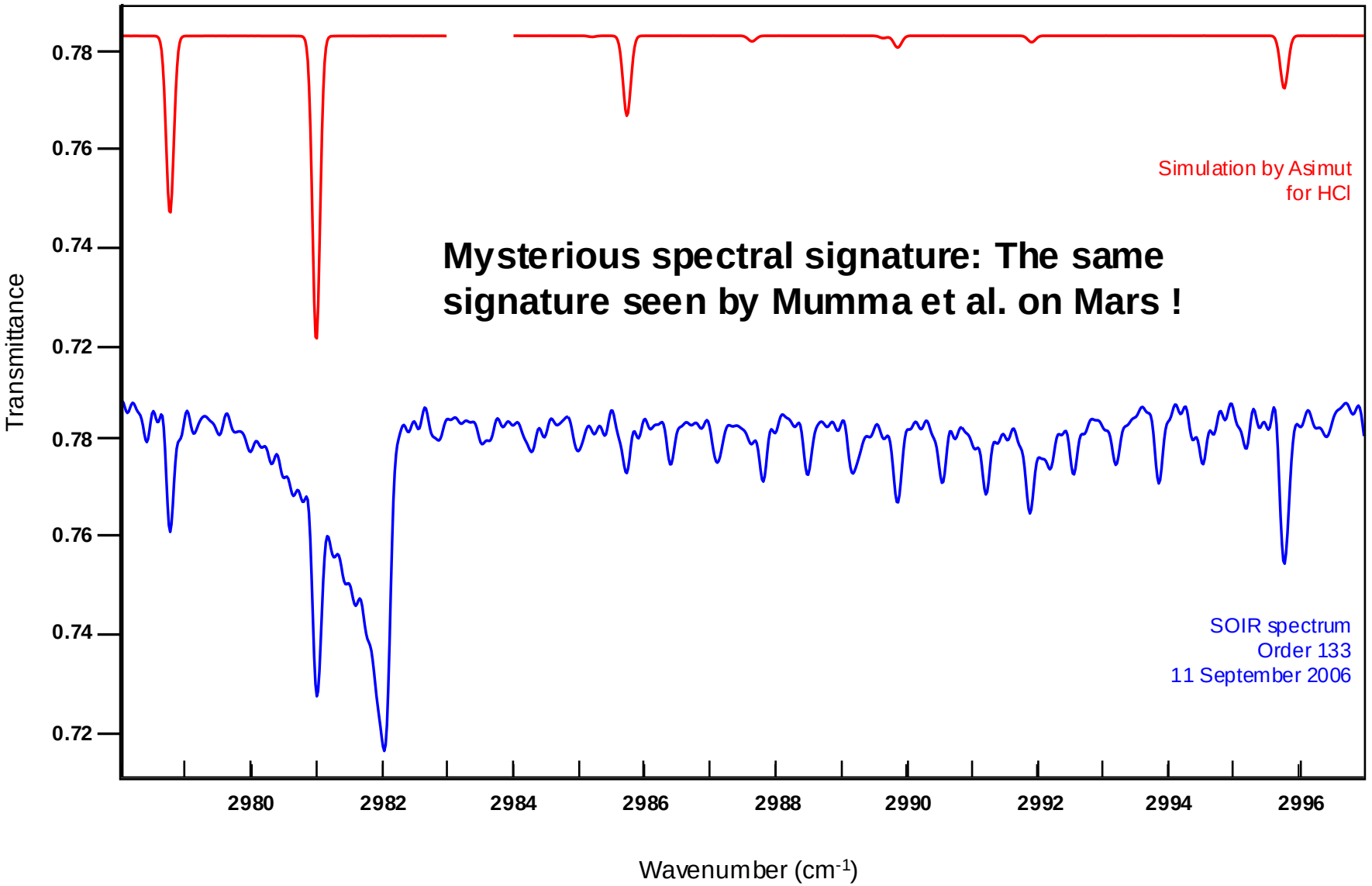
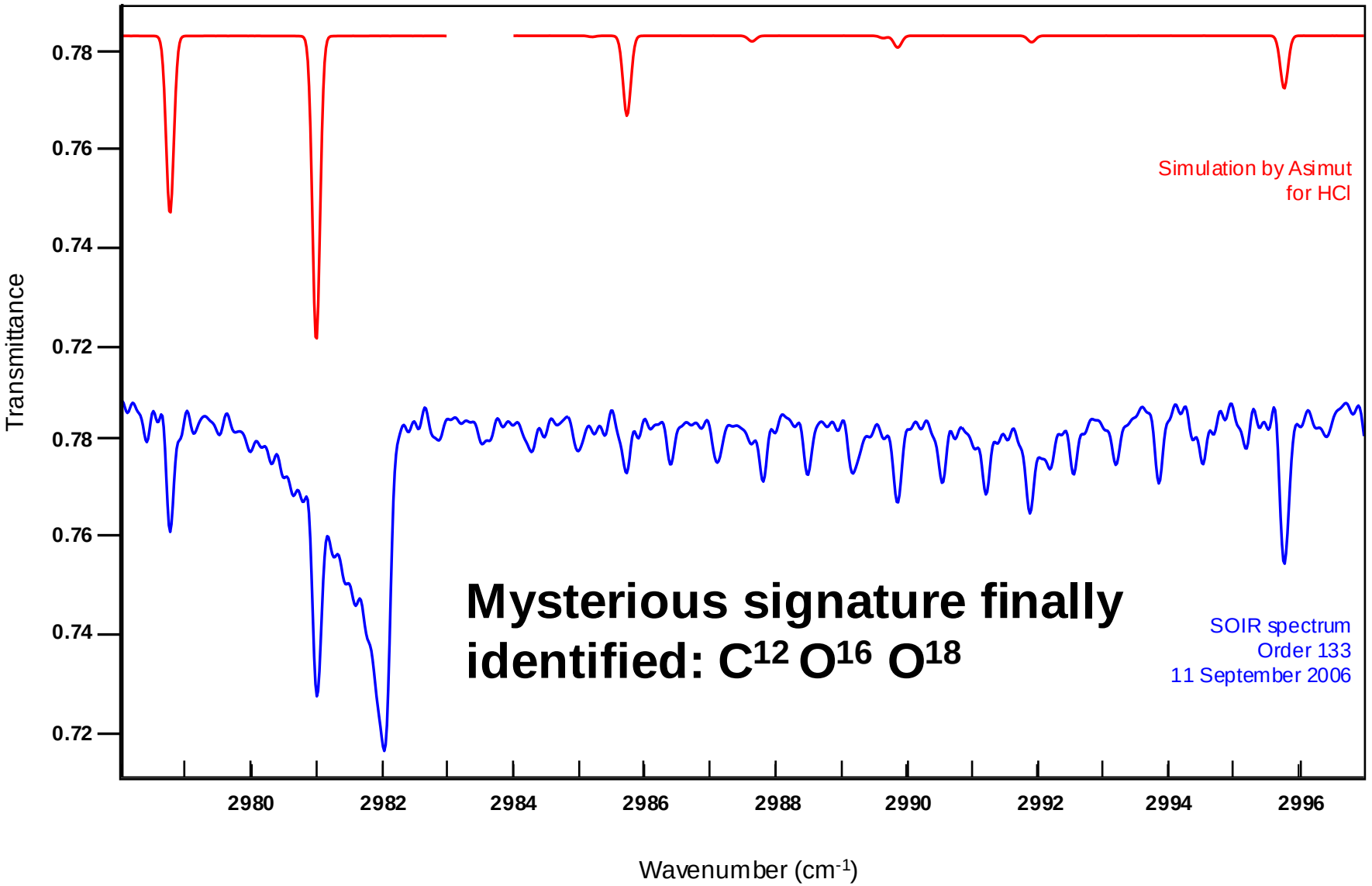
- 150x3 cm= 4.5 m
- Preferential condensation of HDO in ice (exists on Earth at tropopause, loss of a factor of 3), could prevent D atoms from reaching escape altitude (250 km)
- Exists also on Mars

- Does it exist also on Venus ? **SOIR finding: NO !**
- **Escape of D is possible: certainly more than 4.5 m**
- **We wait for detection of D^+ escape by ASPERA on VEX.**


Mysterious spectral signature :
not existing in HITRAN data base
Transmittance
Wavenumber (cm-1)
Altitude (km)
1.0
0.8
0.6
0.4
0.2
0.0
2975
2980
2985
2990
2995
95
90
85
80
75
70

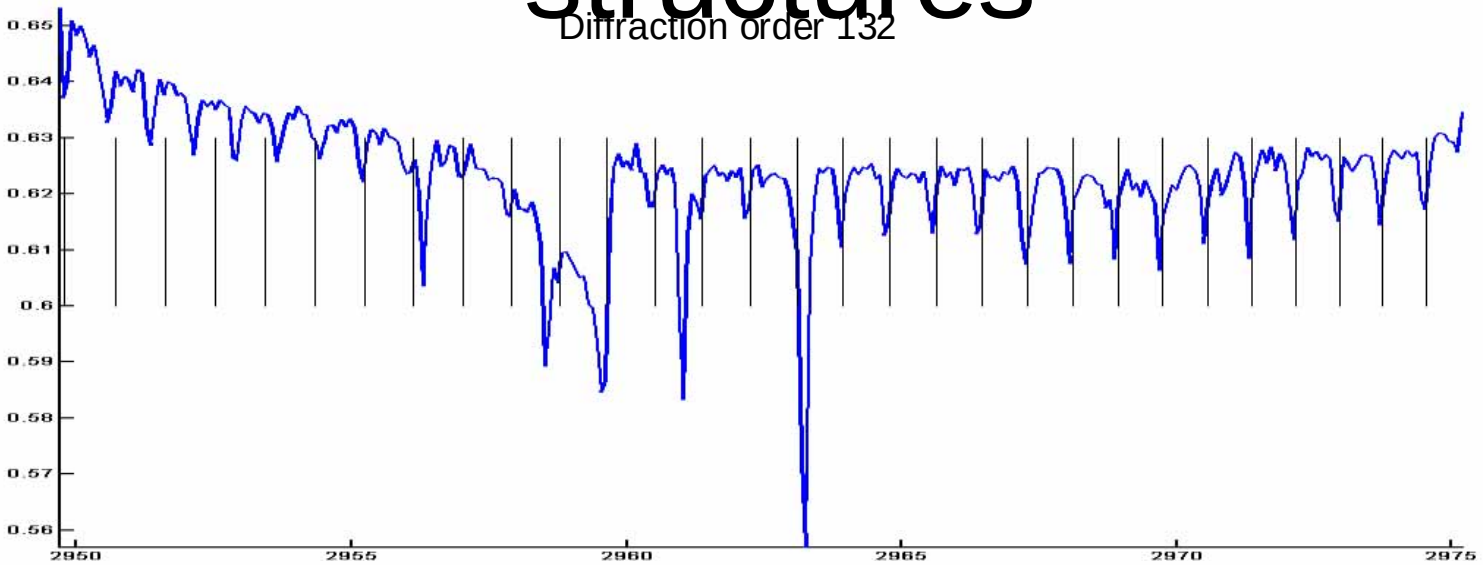

Transmittance
0.78
0.76
0.74
0.72
0.78
0.76
0.74
0.72
2980
2982
2984
2986
2988
2990
2992
2994
2996
Wavenumber (cm-1)
Simulation by Asimut
for HCl
Mysterious spectral signature: 2982
cm-1 typical of C-H bond (organic)
SOIR spectrum
Order 133
11 September 2006


Mysterious spectral signature: The same signature seen by Mumma et al. on Mars !
Simulation by Asimut for HCl
SOIR spectrum
Order 133
11 September 2006
Transmittance
0.78
0.76
0.74
0.72
0.78
0.76
0.74
0.72
2980
2982
2984
2986
2988
2990
2992
2994
2996
Wavenumber (cm-1)

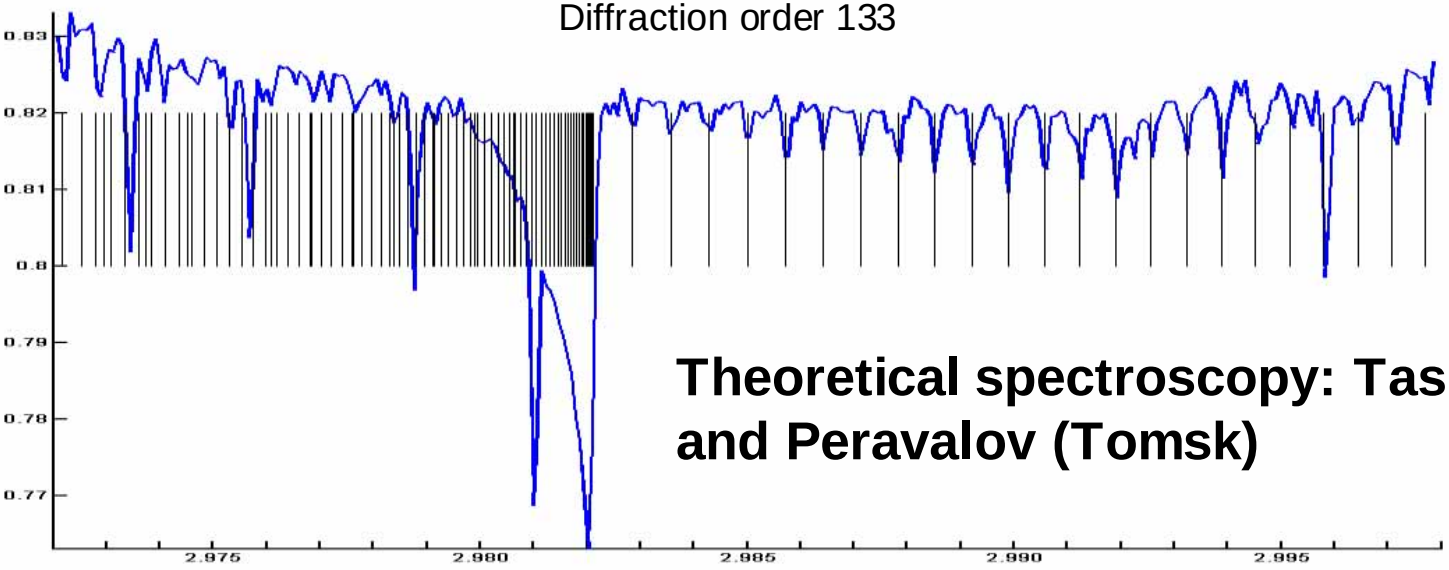

Transmittance
0.78
0.76
0.74
0.72
0.78
0.76
0.74
0.72
2980
2982
2984
2986
2988
2990
2992
2994
2996
Wavenumber (cm-1)
Simulation by Asimut
for HCl
Mysterious signature finally identified: C12 O16 O18
SOIR spectrum
Order 133
11 September 2006

V- Identification of absorption structures

Diffraction order 132



Diffraction order 133



Theoretical spectroscopy: Tashkun and Peravalov (Tomsk)

Consequences of new 628 CO2 band at 3.3 µm

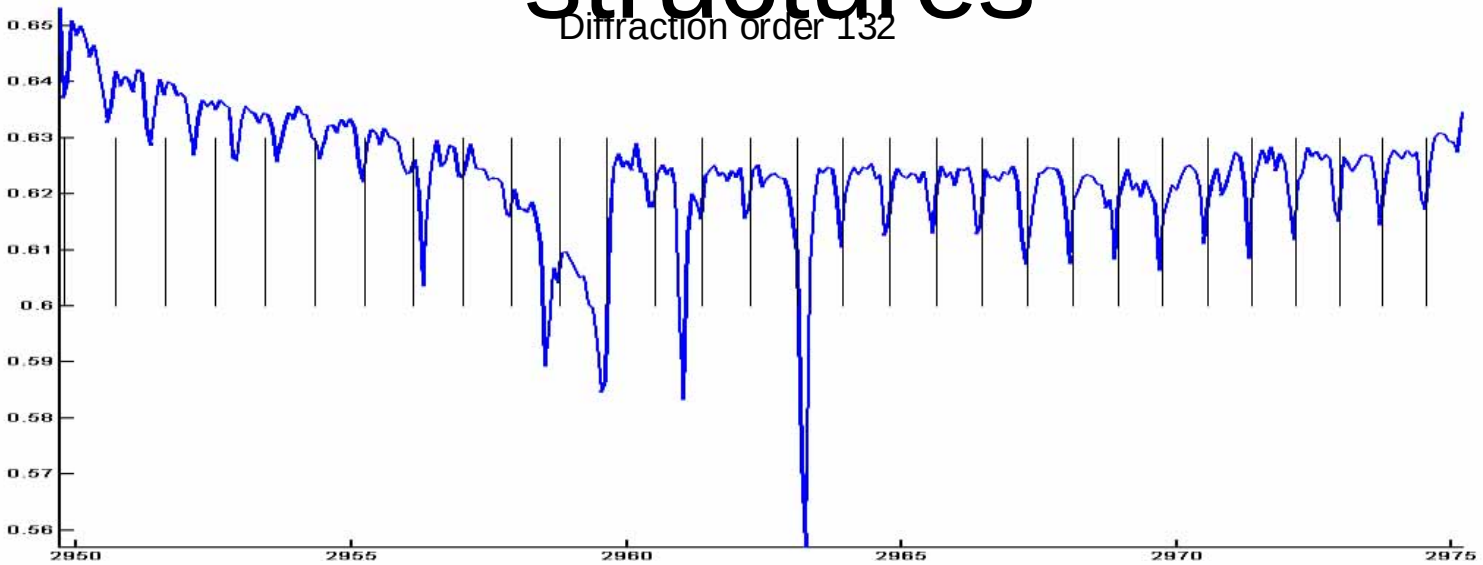
- Increased greenhouse effect on Venus
- Possible confusion with organic biomarker gases , at Mars (and extra-solar planets !)
- (Villenueva, Mumma et al.,Icarus, DPS 2007)
- Emphasis on the need of high spectral resolution to study biomarkers

Conclusions

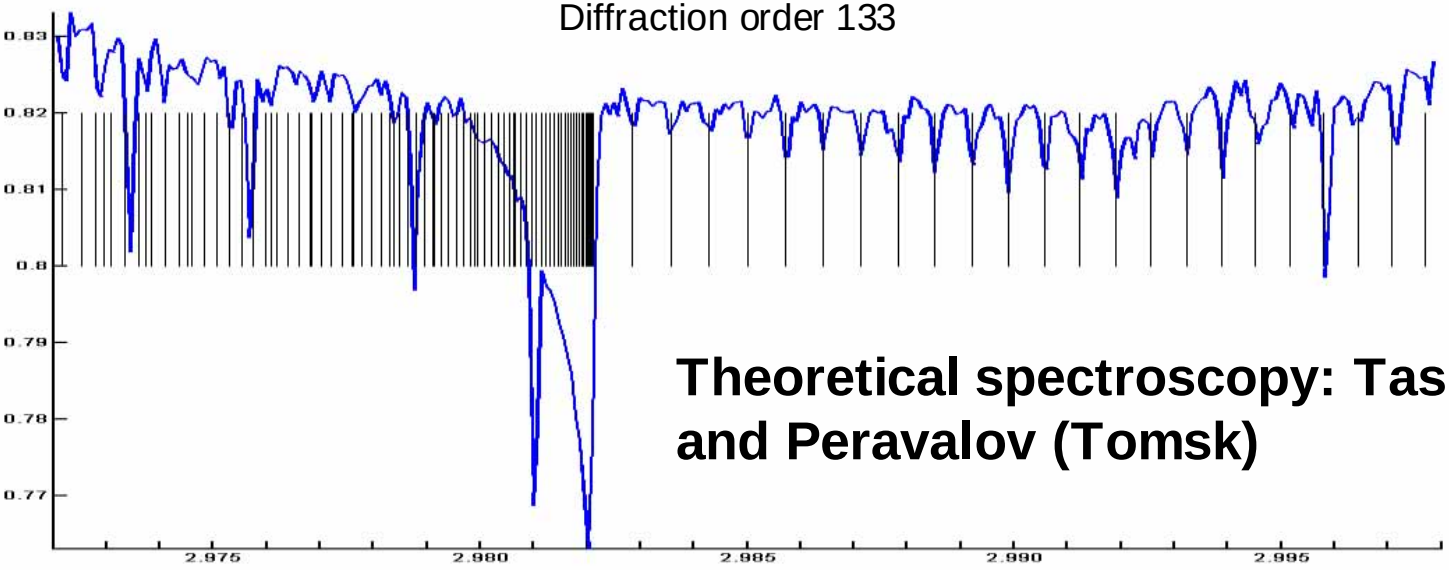
- Just the beginning of Venus Express: SOIR detected CO_2 and isotope 628,H_2O and HDO HCl, HF, CO, and SO_2.
- Venus is the only Earth like planet within a few parsecs from the sun!
- SOIR uses the atmosphere of Venus as a gigantic laboratory of spectroscopy and fundamental physics.

V- Identification of absorption structures

Diffraction order 132



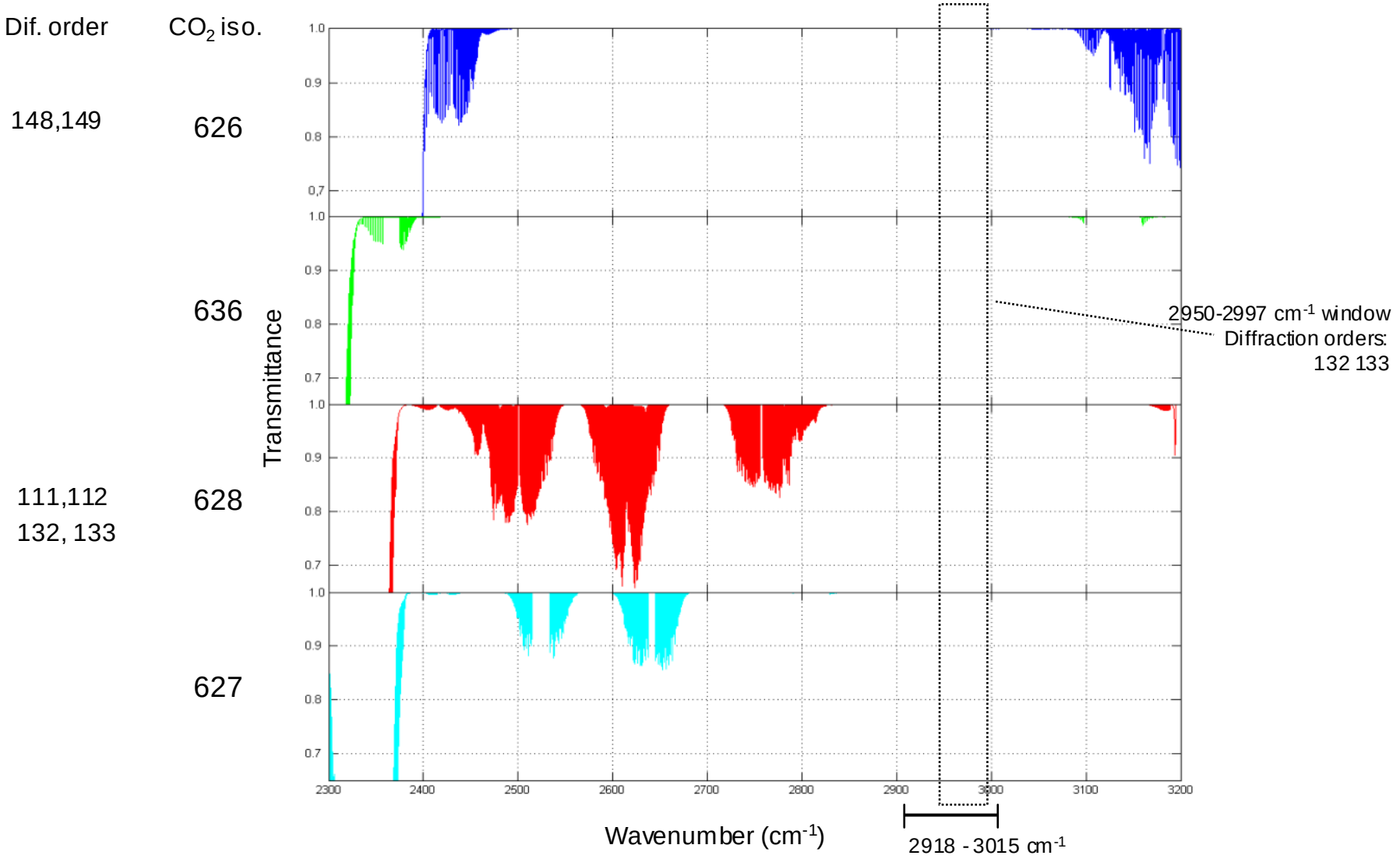
Diffraction order 133

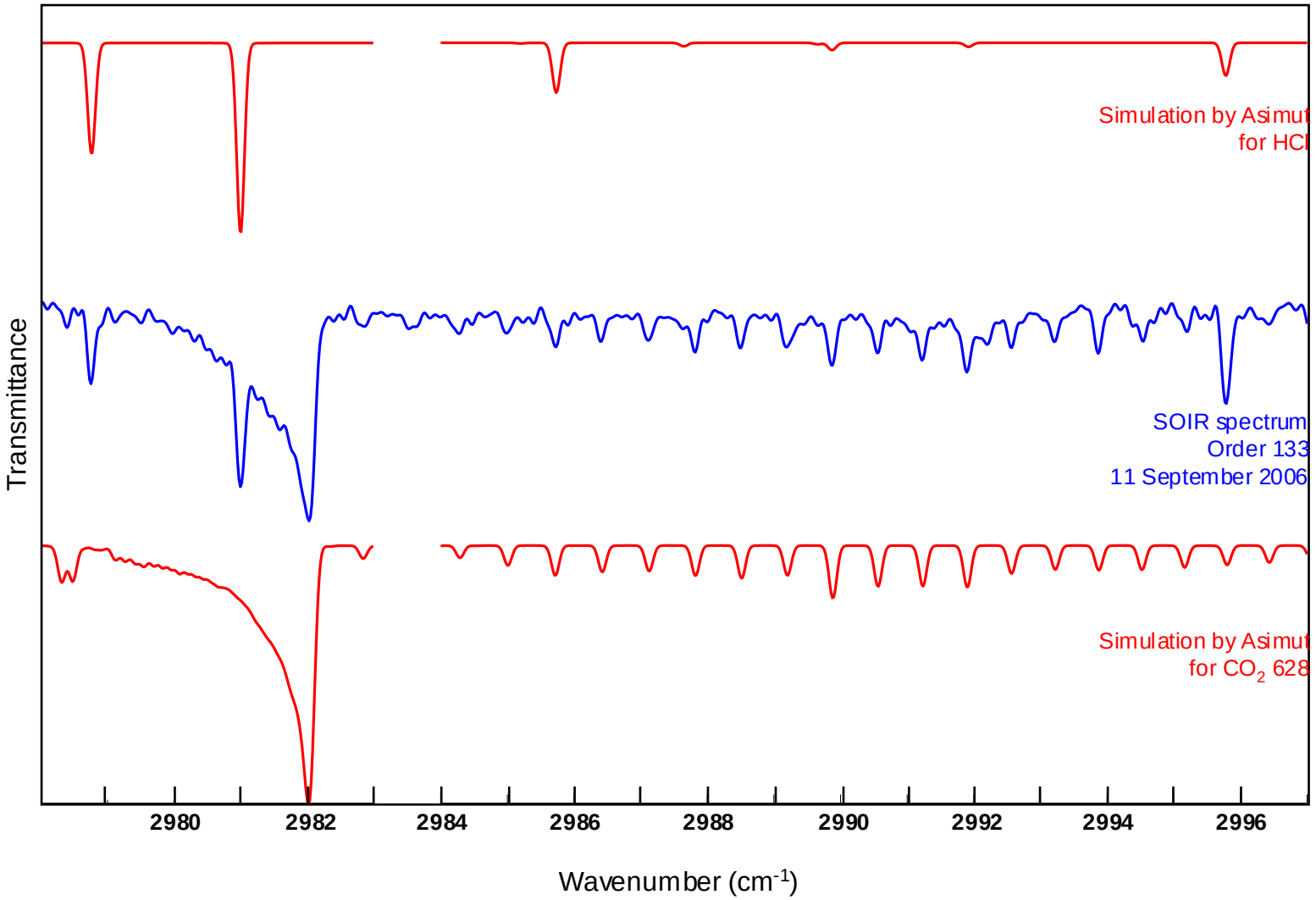


Theoretical spectroscopy: Tashkun and Peravalov (Tomsk)

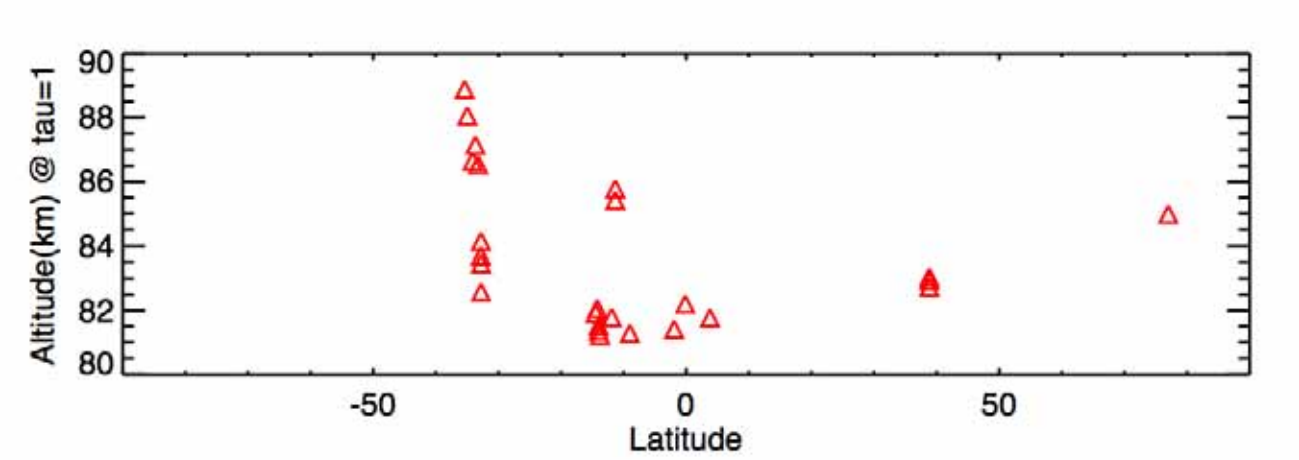
V- Identification of absorption structures

CDSD database for the 4 most abundant CO_2 isotopologues

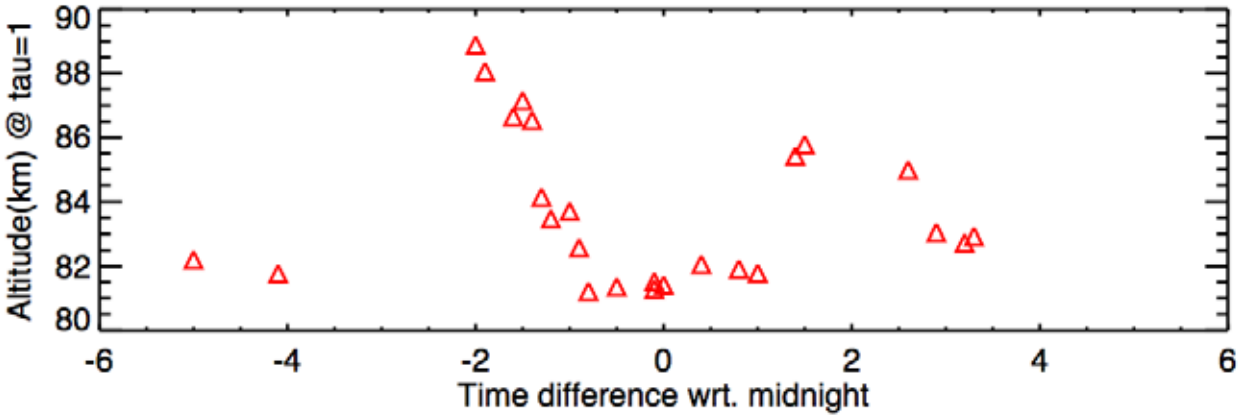



Simulation by Asimut
for HCl
SOIR spectrum
Order 133
11 September 2006
Simulation by Asimut
for CO_2 628
Transmittance
2980
2982
2984
2986
2988
2990
2992
2994
2996
Wavenumber (cm^{-1})

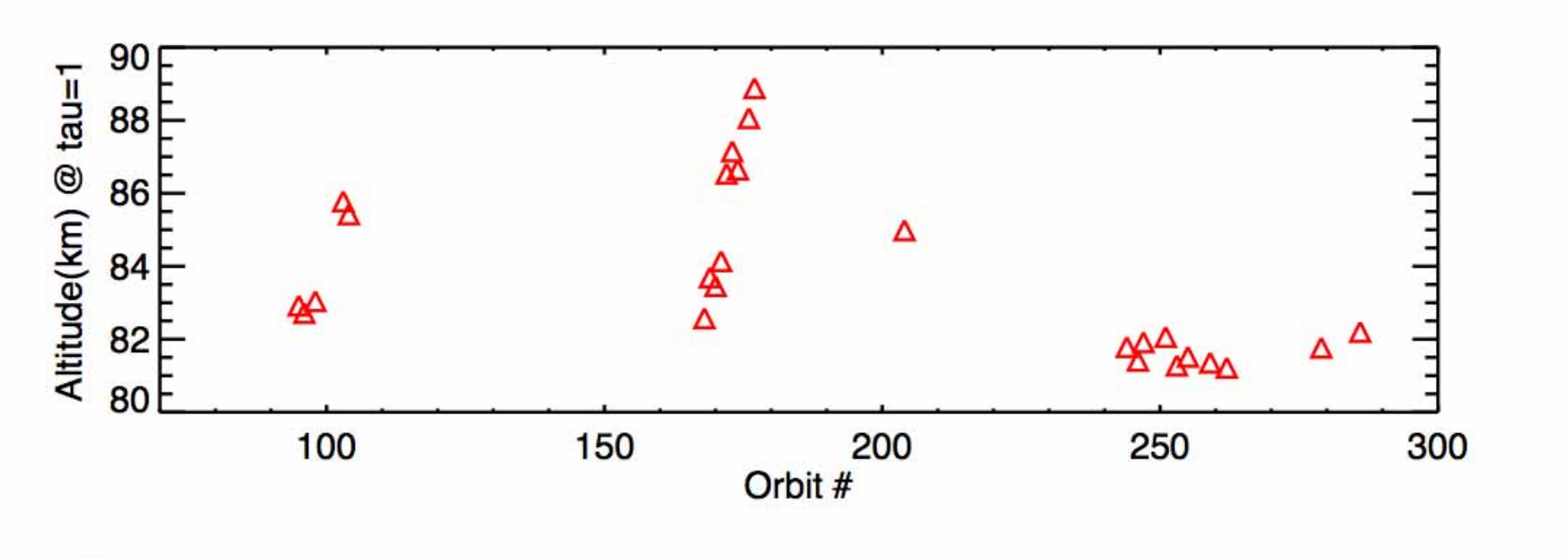
Haze top variations



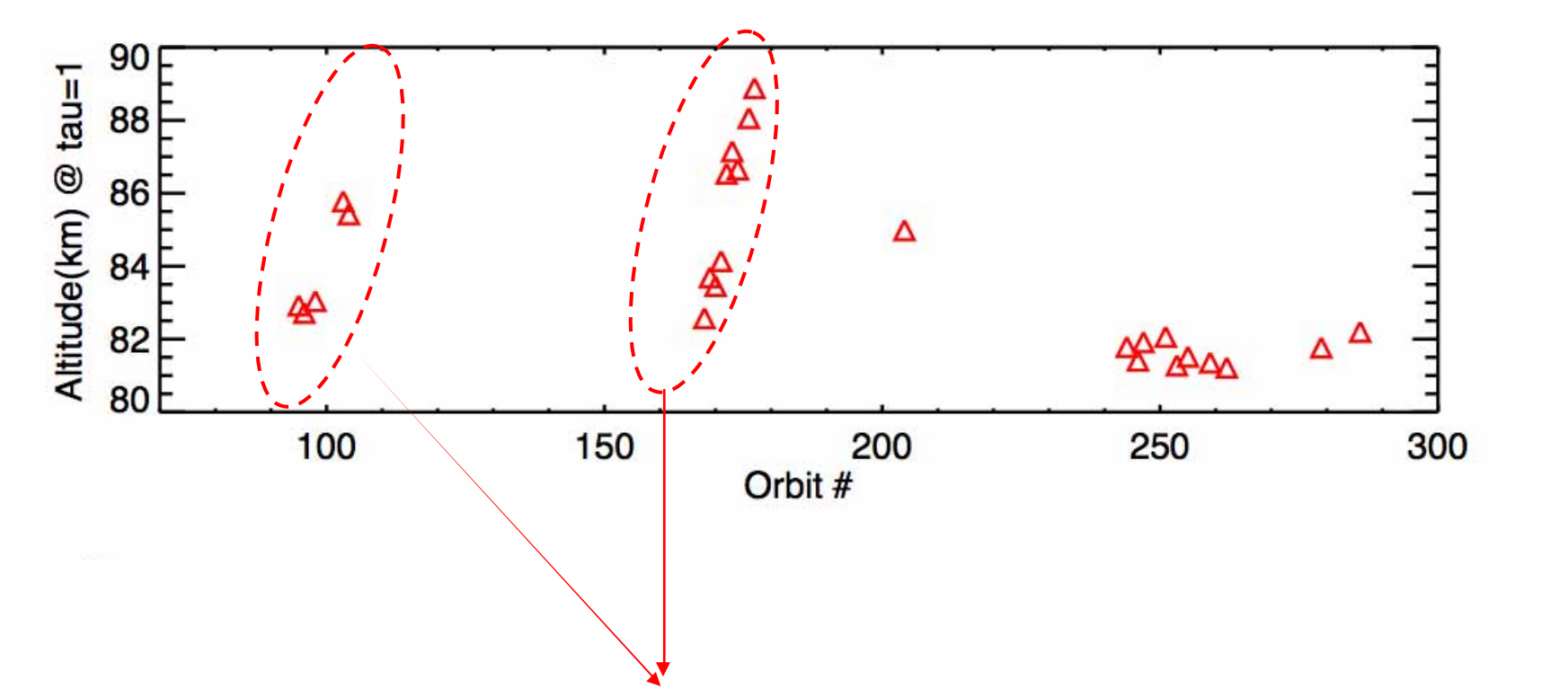
- Upper haze top level (defined by τ=1) shows variations of altitude of almost 10 km during the first 300 orbits



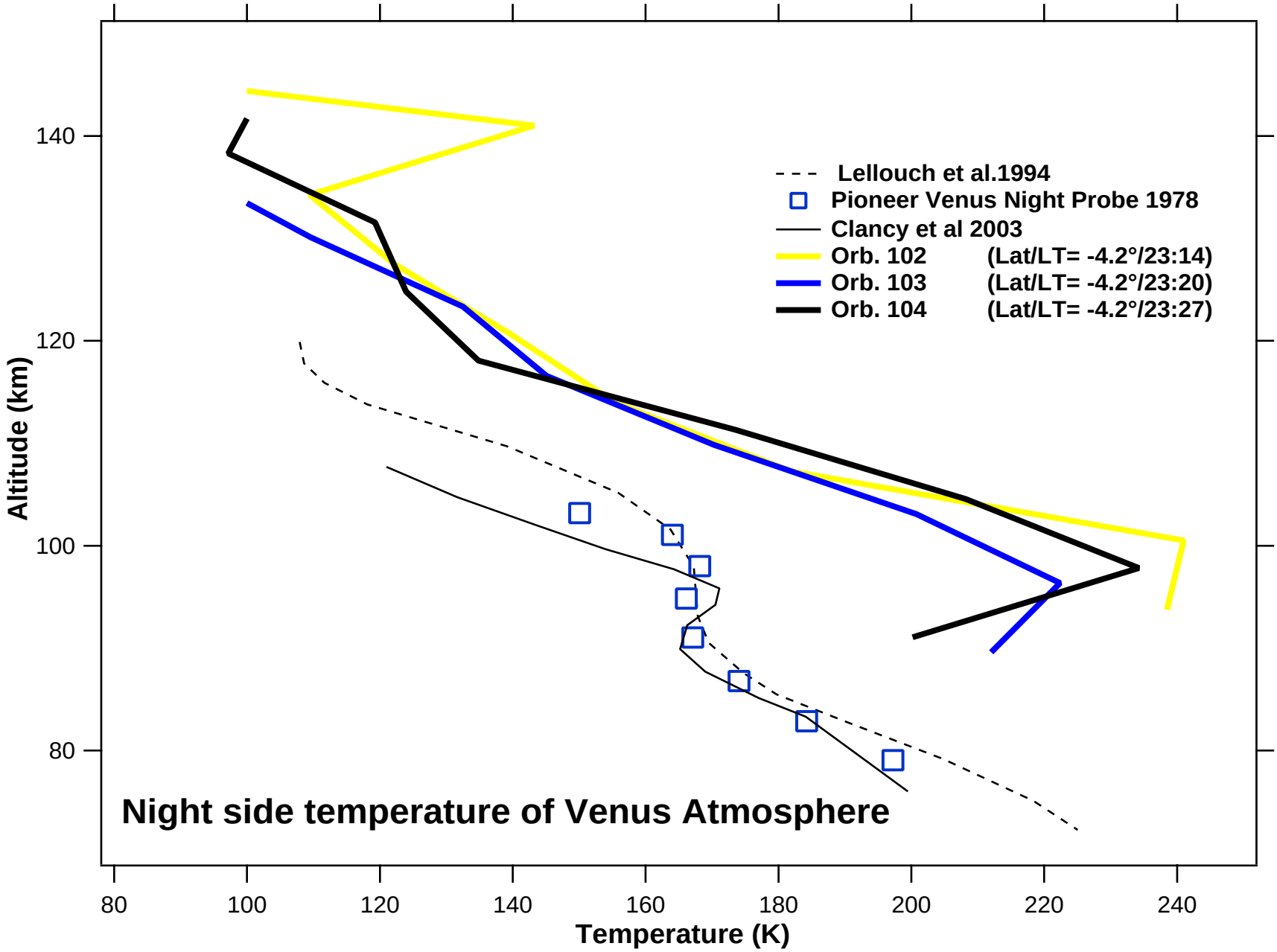
Haze top variations



Haze top variations



Mysterious 9-day oscillation?
See *Forbes et al., yesterday*


Lellouch et al.1994
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Orb. 104 (Lat/LT= -4.2°/23:27)
Night side temperature of Venus Atmosphere
Altitude (km)
140
120
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140
160
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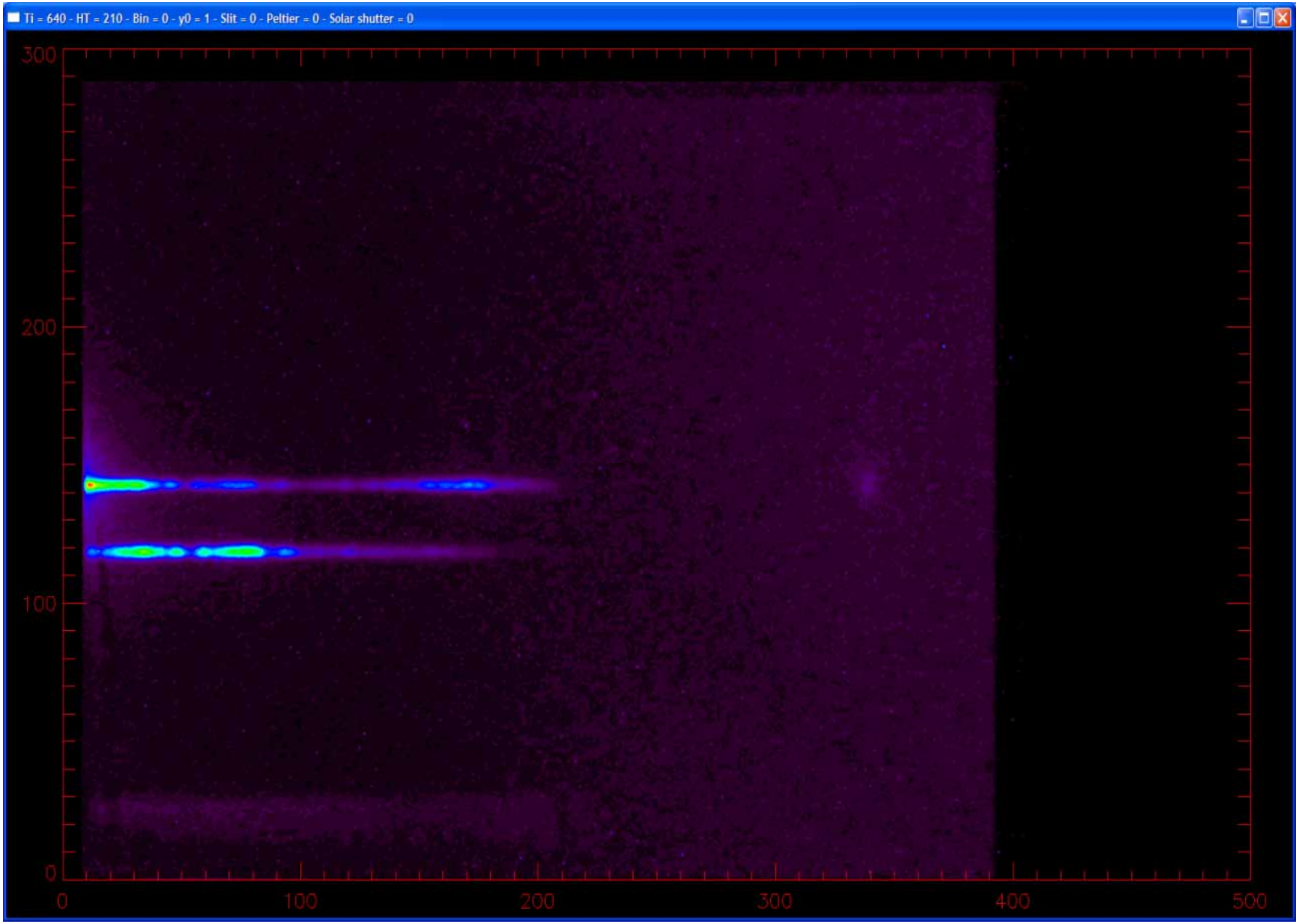
220
240
Temperature (K)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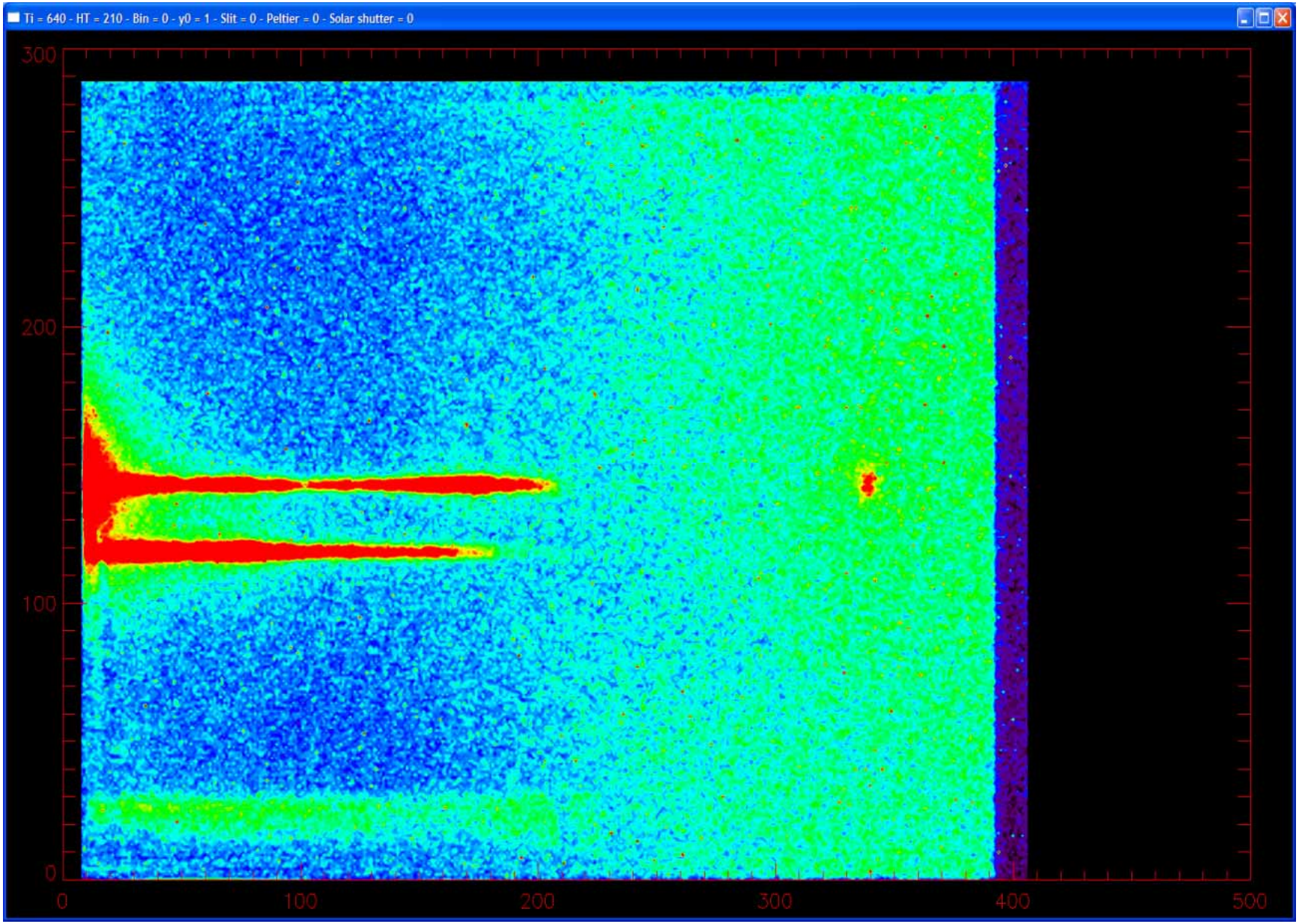
300
200
100
0
0
100
200
300
400
500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300
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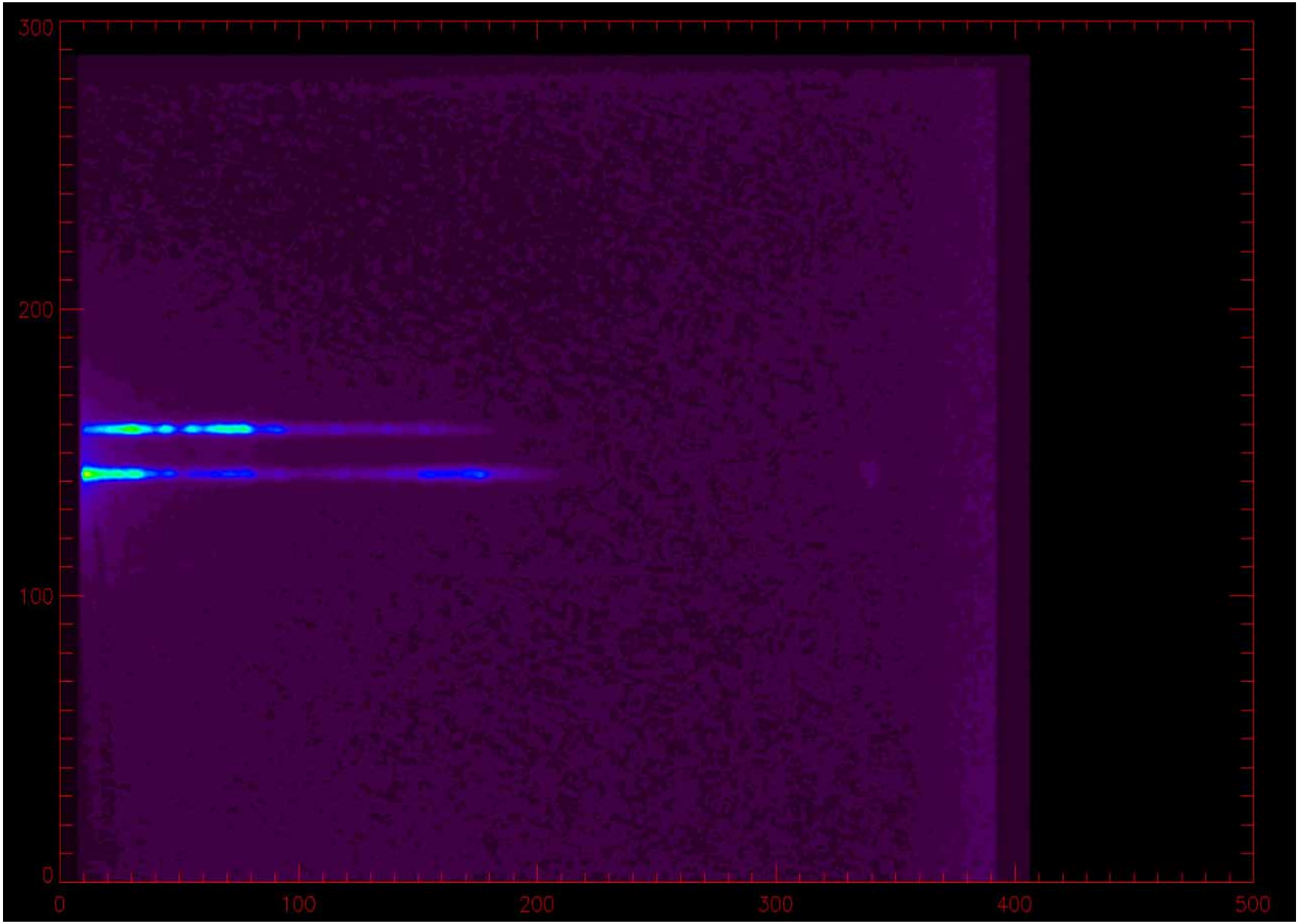
300
200
100
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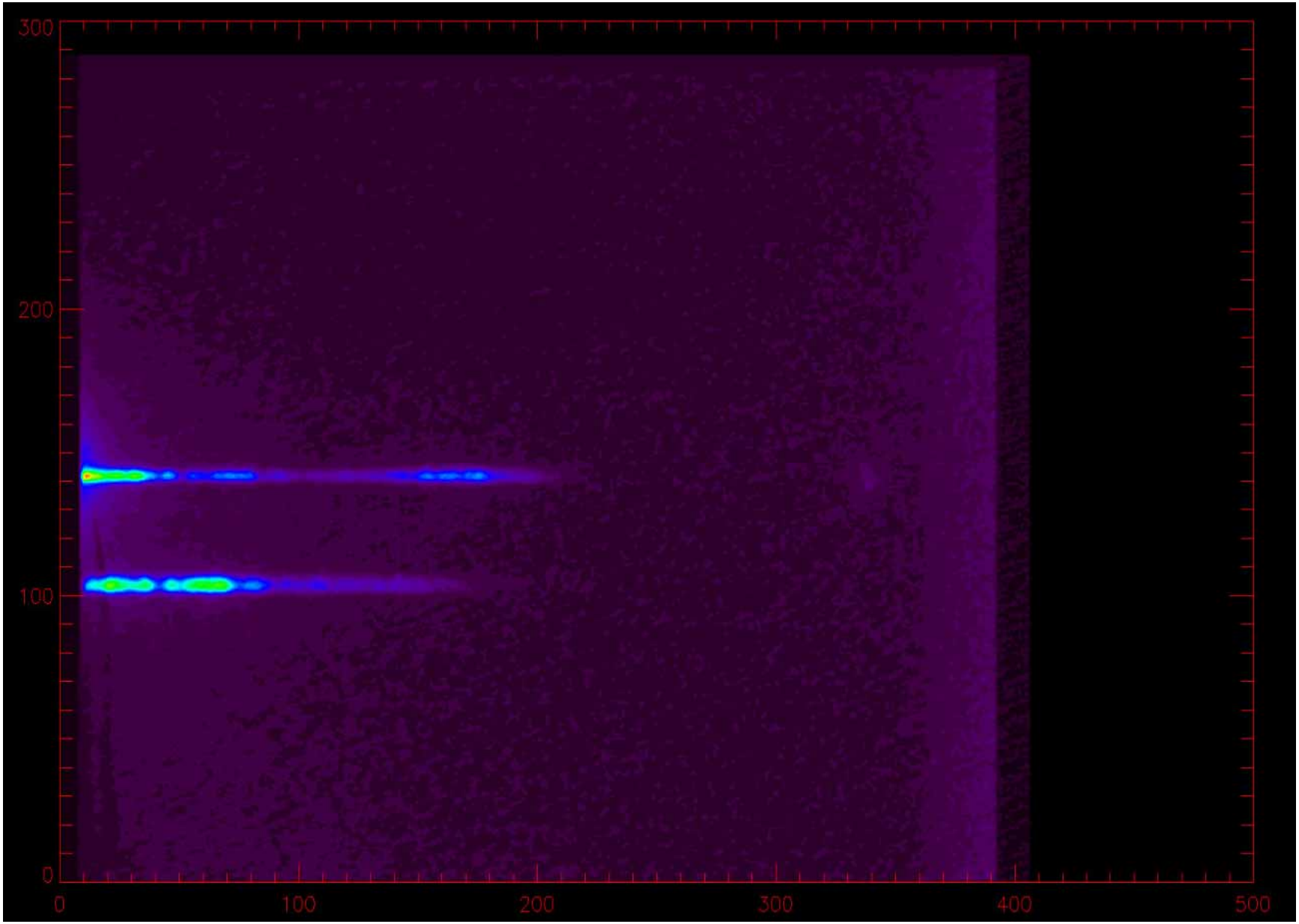
300
200
100
0
0
100
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300
400
500

Earth Observations

Scientific Objectives

- IR AOTF spectrometer (0.63-1.7 μm):
  - Composition of the nightside lower atmosphere by detection of thermal emission
  - Vertical structure of H_2O, CO_2 and **aerosols in solar occultation**
- *UV spectrometer* (118-320 nm)
  - Observation of the NO, O and O_2 emissions in the upper atmosphere on the night side
  - **Measurement of the vertical distribution of CO_2 and aerosols, in stellar occultation**
  - **Determination of temperature and density vertical profiles**
  - Study of the escape processes of H and O atoms by observing the Lyman-α and O emissions
- *SOIR spectrometer* (2.3-4.3 μm)
  - **Measurement of the vertical distribution of many species above the cloud deck (HDO, H_2O,HCl,HF** and isotopes of CO_2, in particular)
  - Sensitive search for new species